The Shop Wisdom
of Philip Duclos

THE HOME SHOP MACHINIST

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Edited by Joe D. Rice

Village Press, Inc.
Traverse City, Michigan

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INTRODUCTION

I love surprises. Totally out of the blue, in early 1984, an unsolicited article came to my office. Its title was "A Temporary Self-locking Stub Mandrel." In the third year of existence for *The Home Shop Machinist*, I was receiving a fair amount of good quality machining articles, so this one did not seem so unusual. However, it was to be the beginning of a seemingly never-ending string of superb articles from Philip Duclos covering the spectrum – foundry related subjects, machining techniques, and accessories and hobby projects to build.

When that first article arrived, what immediately stuck me was the superior photography. Phil clearly knew how to take a picture that was in focus, composed carefully, properly balanced from black to white, and said what it needed to say. Furthermore, he laid out his text in a linear, logical fashion that required editing only for *HSM* style. (An editor always appreciates people like this!)

As one fine article after another kept appearing, I began to see what a treasure was being bestowed upon me, as editor, and you, as reader. When the first hobby project, "Odds 'n Ends Hit 'n Miss Engine" arrived, there was no more wondering about the limits of Phil's skill and imagination – he has no limits. It still stands as the most popular hobby project we ever published in *The Home Shop Machinist.*

What delights me most are his unique little stationary engines. They are offbeat, bright, and beautiful, and they run like champs. Some look like space age inventions, but they operate on the same principles that were discovered ages ago.

In a mere six years, Philip Duclos has amassed an impressive array of articles and projects, and I can think of no better way to salute his creativity than to pull all his work together into book form, and call it "Shop Wisdom..." I could as easily and appropriately call it "Shop Joy...," because it's clear to me that he does all this with a fire of delight burning brightly inside him every moment he's at play (work) in his shop. I trust some of his joy will spill out and over you as you read this book.

Joe Rice, Editor

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TABLE OF CONTENTS

Shop Projects & Techniques

2 Model Maker's Dividing Head
24 "Floating" End Mill Sharpener
37 Unorthodox Mill/Lathe Grinder
44 Old Lathe Collet Adapters
49 "Slow Poke" Small Keyway Broach
54 Temporary Self-locking Stub Mandrel
56 Adjustable Parallels
60 A Temporary Aluminum Furnace
62 Degassing Molten Aluminum
64 10" Super Colossal Fly Cutter
66 A Showpiece Challenge
68 Give Metal Spinning a Whirl

Hobby Projects

80 Odds 'n Ends Hit 'n Miss Engine
108 Smallest "Hit & Miss" Gas Engine?
112 Model Piston Rings
115 Curved Spoke Flywheel
124 "Whatzit" Engine
141 Six-cycle Oddball Engine
175 A Huff 'n Puff Engine
188 Fire Eater Engine

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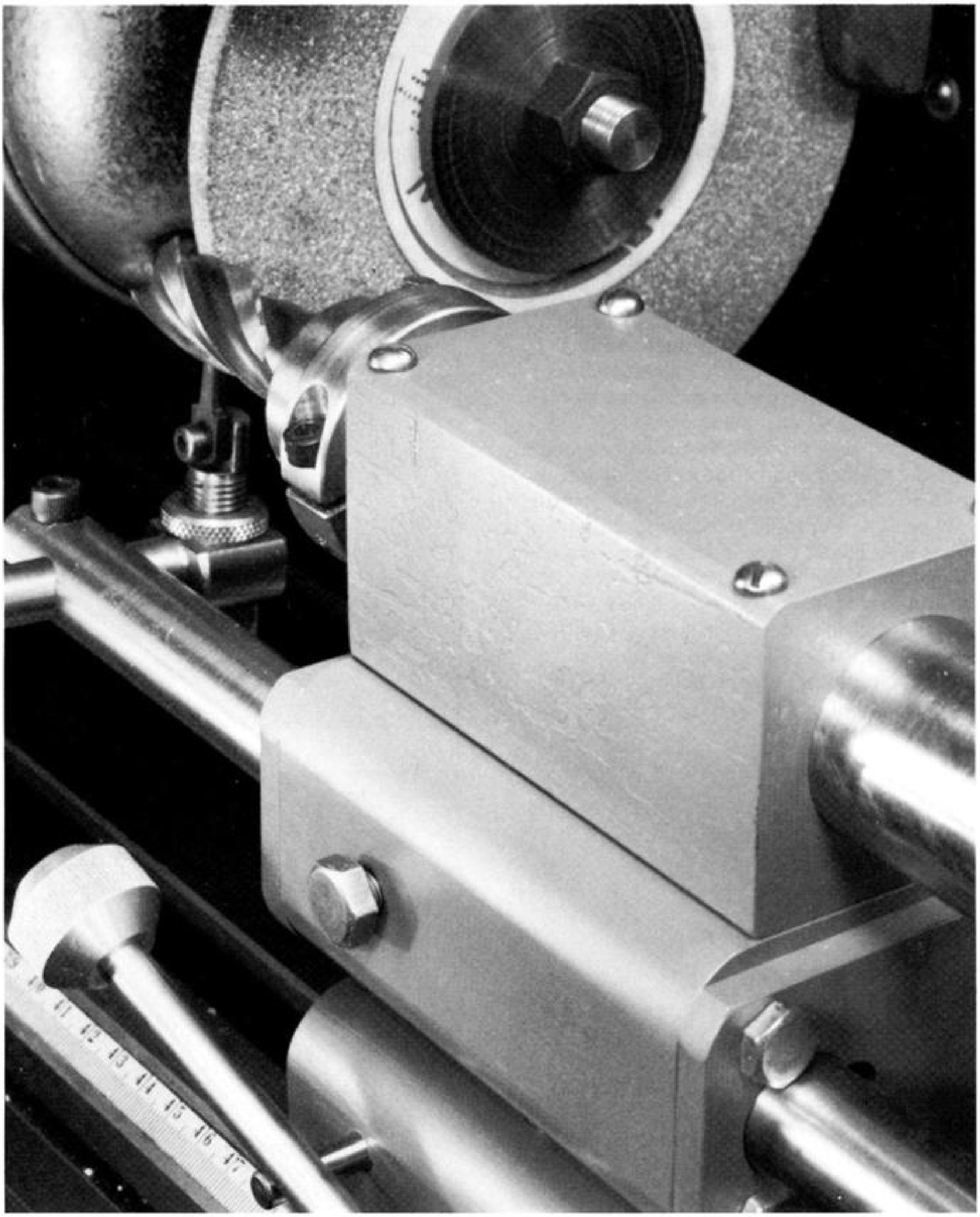
Shop Projects & Techniques

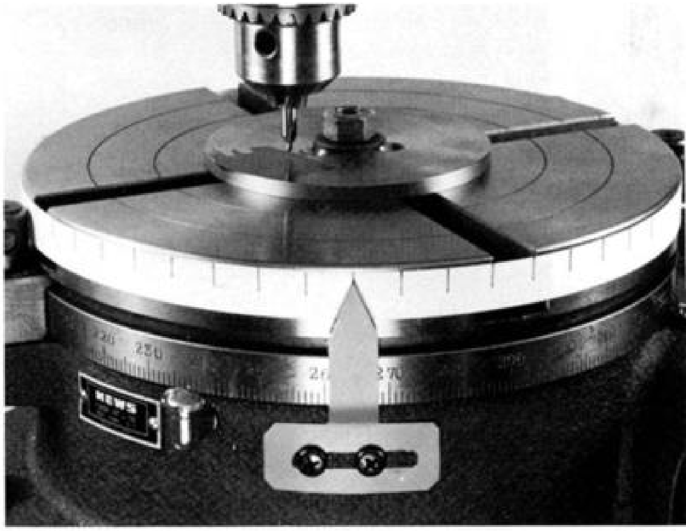


Model Maker's Dividing Head

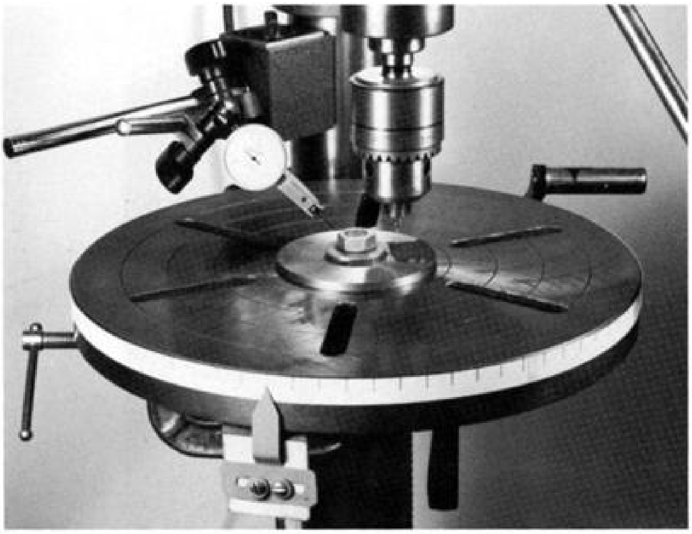
A typical dividing head is considered a rather precise piece of equipment; at first glance it would appear to be of complex construction and out of bounds for the home shop machinist to build. No so! I fabricated mine from odds and ends I had lying about and it turned out just fine. Though it's smaller in size (4-1/2" swing) than a commercial divider, it'll handle most jobs for the model maker. It is capable of most divisions between 2 and 400 or more. With this divider you'll be able to make spur gears, bevel gears, special reamers, taps, bevel cutters, etc.

Initially, it would seem that the greatest obstacle facing anyone wishing to build a dividing head would be the indexing plates. These plates, with their intimidating spiral of meticulously spaced holes, are, in fact, amazingly easy to make. By utilizing a simple age-old method of dividing a given distance into any number of equal spaces, the drilling can be done – even on an ordinary drill press! Photos A, B, and C show three variations of the idea – A, using a rotating table on a milling machine or drill press; B, using the round rotating table of a drill press; and C, using a drill press with a square table on which a round rotating piece of plywood is clamped. Simple, eh? So relax! Full details will be given later on.

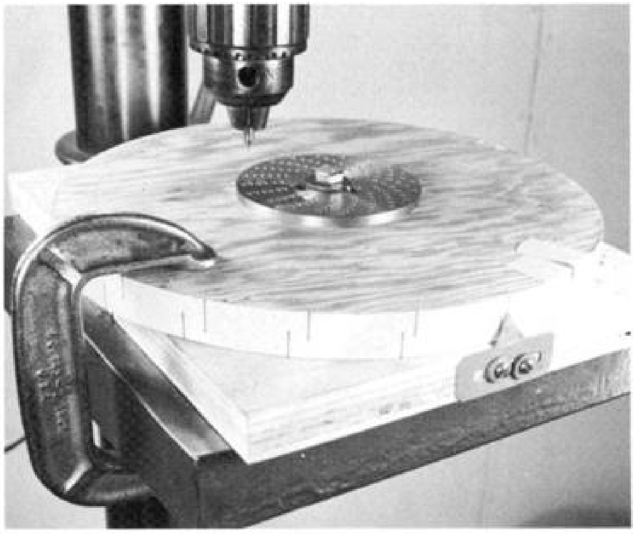
The heart of a divider is the worm and gear drive unit. Such a unit should have a 40-to-1 ratio – that is, the worm turns 40 revolutions to one revolution of the gear. I purchased my drive unit a number of years ago – unfortunately, I could not find a gear with the correct size shaft hole. I solved this problem by hollowing out the gear and fitting it with a new hub. At the right in Photo 1 is a standard worm and gear unit; at the far left is a similar gear, hollowed out. The new hub, shown at the center of the picture, is bolted into the gear's



A



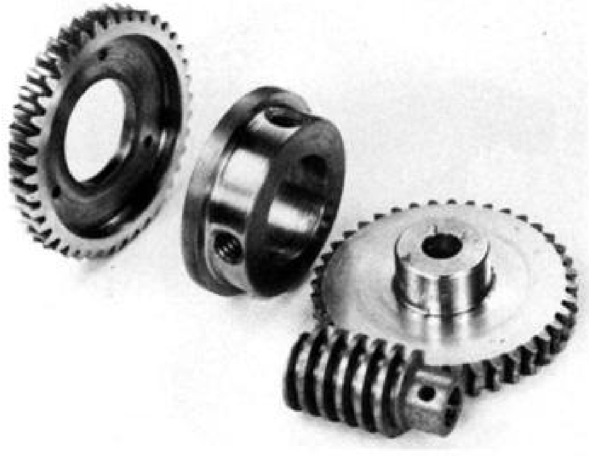
B



C

hollowed section – not much of a problem! There were no identifying marks on my drive unit other than "Boston Gearworks". The worm is about 1-1/16" long by 37/64" in diameter, with a 1/4" bore. The width of the 40-tooth gear is 1/4" and diameter is 1-25/32". Your gear should have a hub similar to the original unit shown in Photo 1 – it's needed to hold the gear while boring it out. It's not critical that your worm and gear have the exact dimensions shown above – but of course any variation that is too large or small will force you to change other dimensions in the dividing head design.

Let's begin things by fitting a new hub in the gear. Drill and thread a hole in the original hub of the gear for an 8-32 or 10-32 setscrew. Then machine a stub arbor that will fit snugly in the shaft hole of the gear; finally, file a small flat on the stub for the setscrew (Photo 2). Bore out the large recess in the gear (Photo 3). Remove that setup from the lathe and start work on a new hub for the gear (Photo 4). The bore should be about .00025" larger than the spindle diameter. Machine the hub flange diameter for a snug fit in the gear cavity. Now lay out and drill three equally spaced flathead bolt holes in the gear (Photo 5), and also three threaded mating holes in the new hub. The hub is mounted on a snug fitting stub arbor and the original hub cut off. Finish the gear by boring it out to the inside diameter of the new hub (Photo 6). Two major pieces of metal are essential to form the divider body and the angle plate (Photo 7). A piece of 4 x 4 x 5/8"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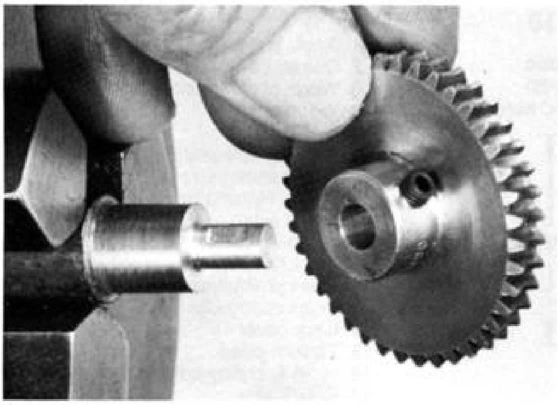
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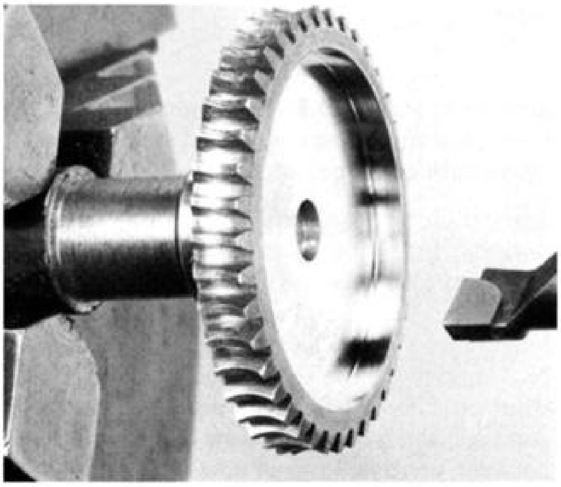
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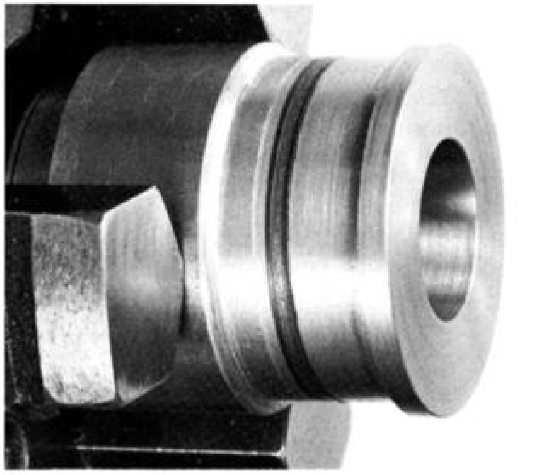
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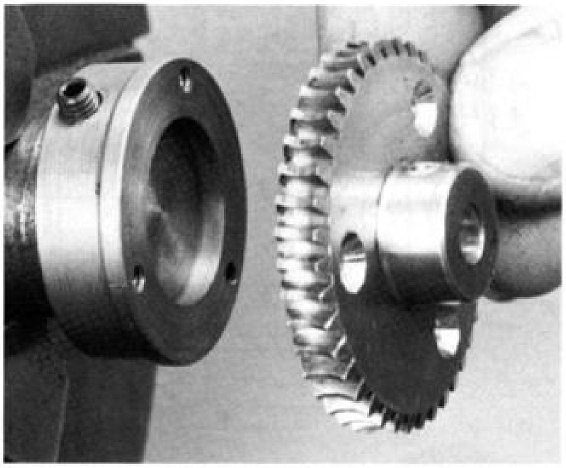
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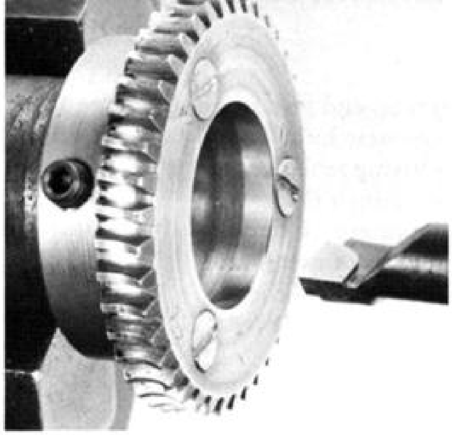

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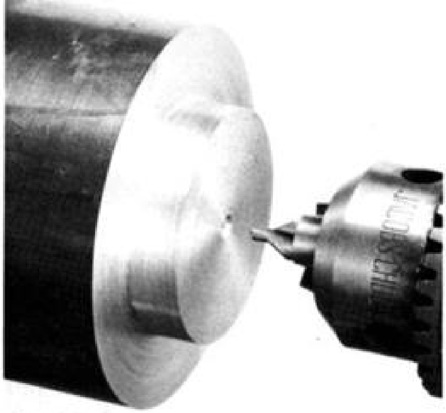

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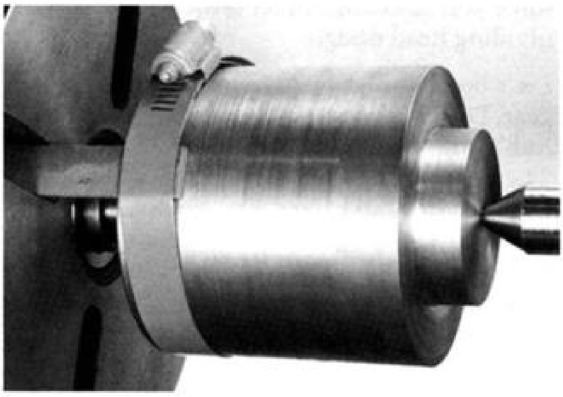
angle iron was used for the angle plate. For the body section, hot or cold rolled steel or even aluminum could be used.

Since there's considerable machining to be done on the divider body, it's advisable to begin work on it first. Chuck up the body in the lathe, face off and center drill each end, leaving the overall length slightly oversize. Now rough-cut the step shoulder about 1/32" oversize (Photo 8). Since all dimensions should run true, the work must now be mounted between centers. I rigged up a temporary dog (a screw-type hose clamp and a piece of steel) to turn the work while machining the two outer faces and then to bring the smaller diameter to its finished size (Photo 9). To true up the divider OD, an adjustable dog was used for a driver (Photo 10).

Now mill or flycut the first flat surface on the round portion of the body (Photo 11). Under stress, a cylindrical piece of metal is more apt to shift in the vise jaws than a square or flat piece, so tighten the jaws securely and take



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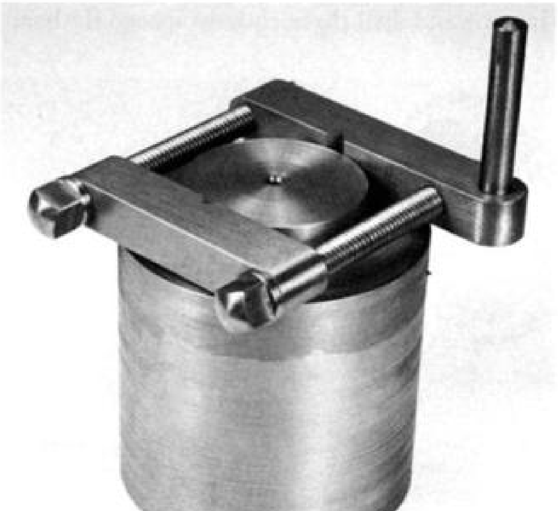

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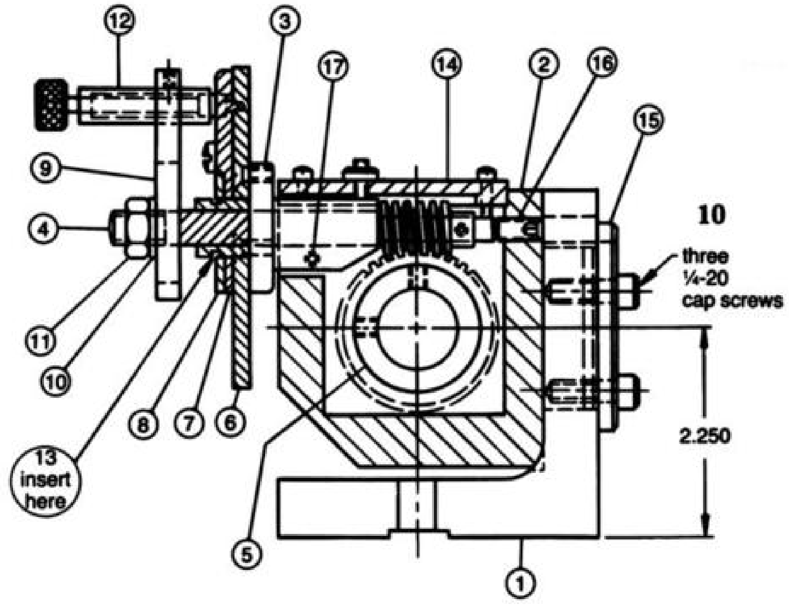
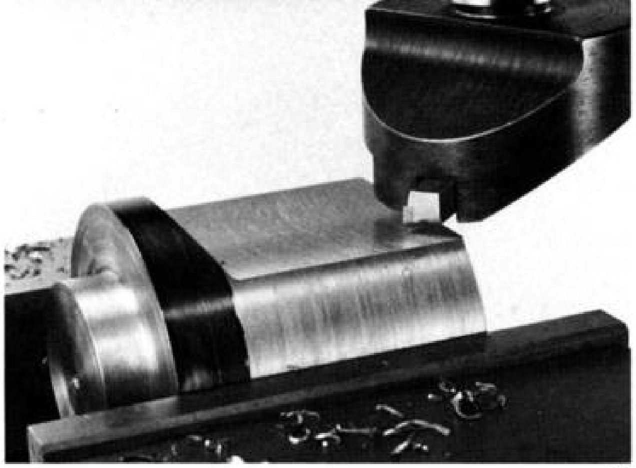


1 Angle plate
2 Divider body
3 Worm shaft housing
4 Worm shaft
5 Gear hub
6 Dividing hole plate
7 Lower sector arm
8 Upper sector arm
9 Crank arm
10 Washer
11 ⅜-24 Nut
12 Index crank pin
13 Index spring clip
14 Gear cover
15 Tilt lock plate
16 ¼-28 End play adjusting screw
17 Pivot bolt



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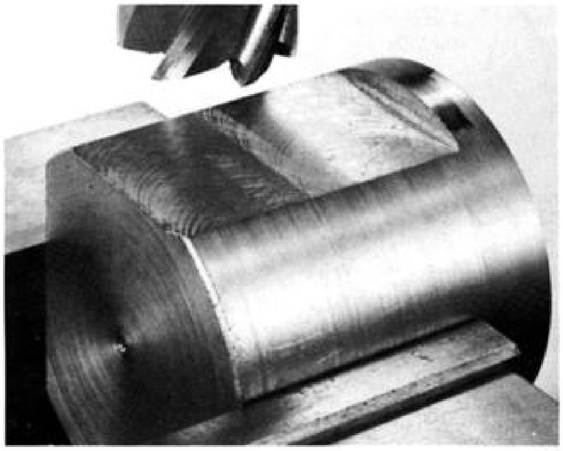

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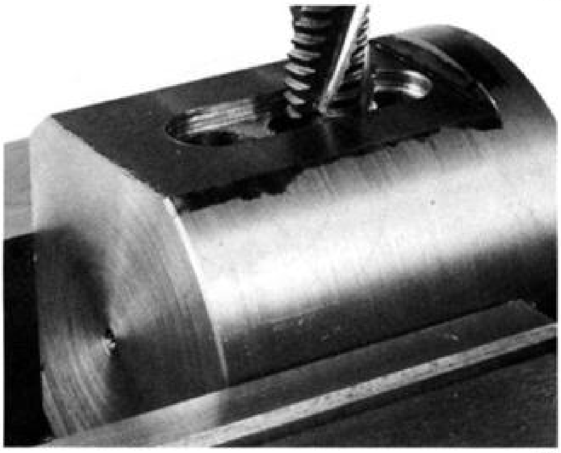
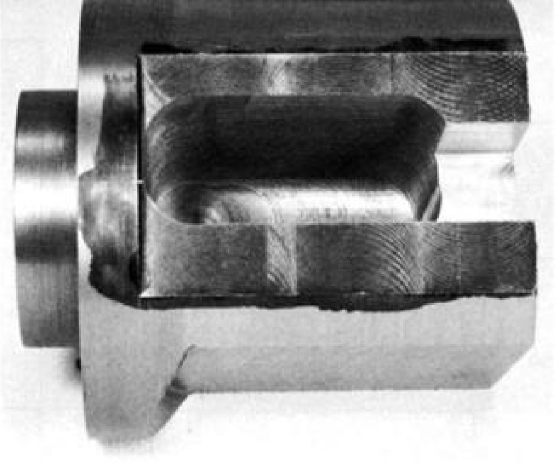


13

light cuts. This flat surface will be the one where the rear end of the spindle will eventually emerge. Next, rotate the workpiece in the vise so the surface just machined is positioned vertically as in Photo 12. Again machine a flat. This will be the upper surface on the body. Apply layout blue to this area and scribe the outlines for the deep cavity that will house the worm and drive gear. Now drill three 1/2" or 9/16" holes within this area to the proper depth. This will eliminate some of the excess material before milling. A long end mill with a cutting length of at least 2-1/4" is



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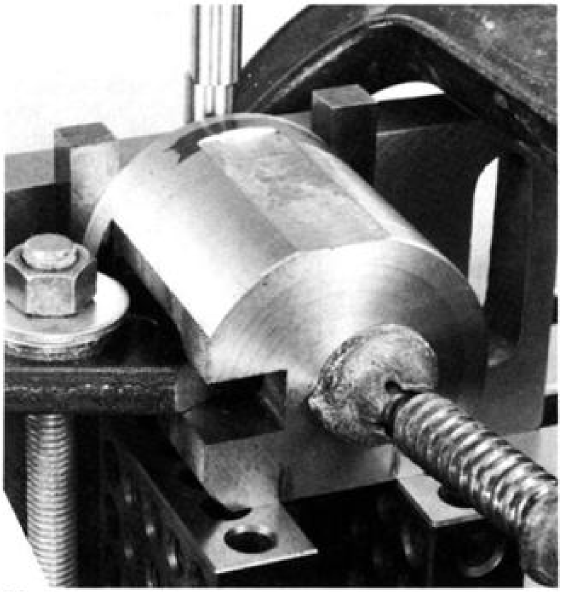
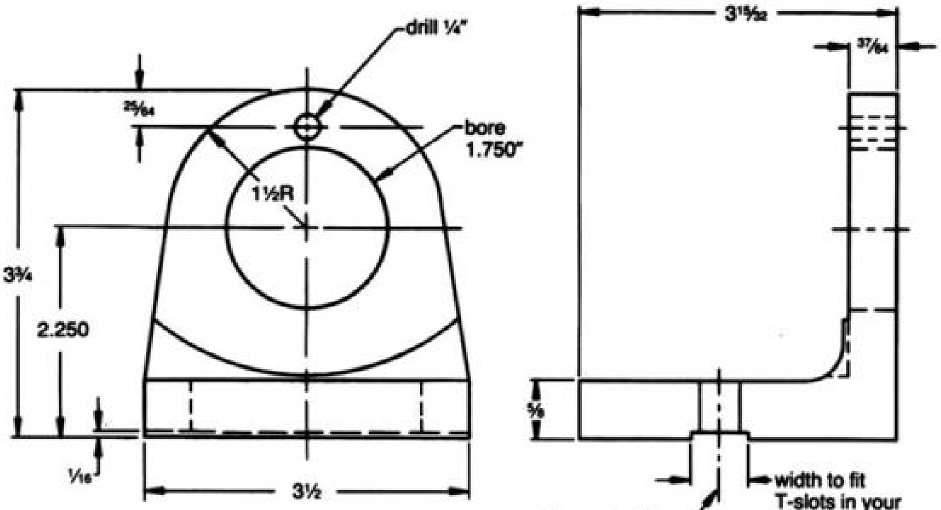


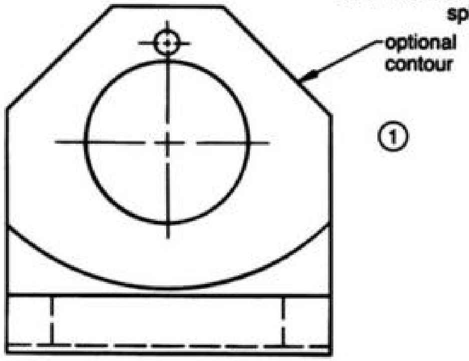
15

necessary to mill out the cavity. I used a 5/8" diameter roughing-out end mill (Photo 13). Long end mills have a sneaky habit of pulling themselves out of collet-type holders; therefore, limit the depth of each cut to about 1/16". To reduce chattering, employ a subnormal spindle speed.

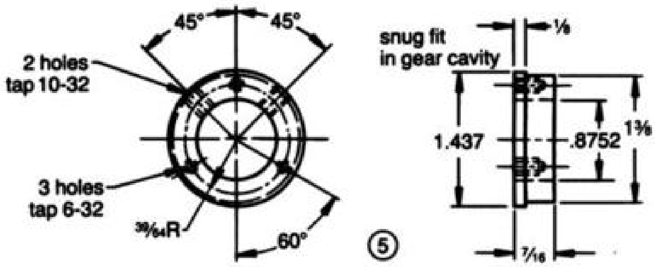
At this time, do not mill out the shallower slot that extends to the end of the workpiece (Photo 14). After each pass with the end mill, stop the machine and use a magnet to lift out the surplus chips in the cavity. Upon reaching the proper depth, mill out the cavity on one side to an overall width of 13/16". Now prepare to machine the slot that extends to the end of the piece. Do not use a roughing end mill. The center line of this slot should be exactly on the center line of the body. You can find this center line by using an edge finder brought to bear against the major diameter of the body. The two vertical walls of the slot should be as parallel as possible since the mating part must fit snugly within it. If you have a resharpened 5/8" end mill that's slightly


drill ¼"
bore 1.750"
²⁵⁄₆₄
1½R
3¾
2.250
¹⁄₁₆
3½
3¹⁵⁄₃₂
³⁷⁄₆₄
⅝
width to fit T-slots in your mill table

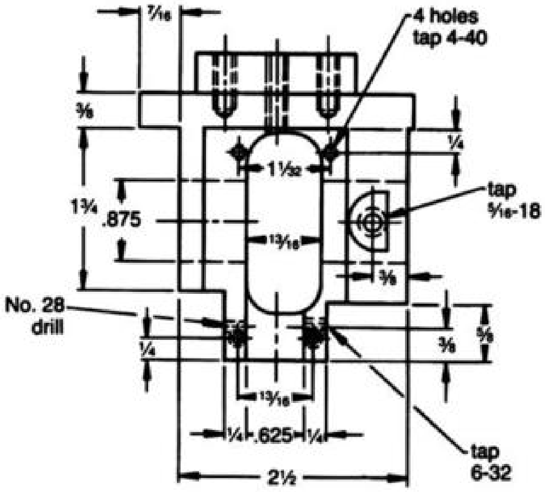
The center line of the slot MUST be in line with the divider spindle hole.


optional contour

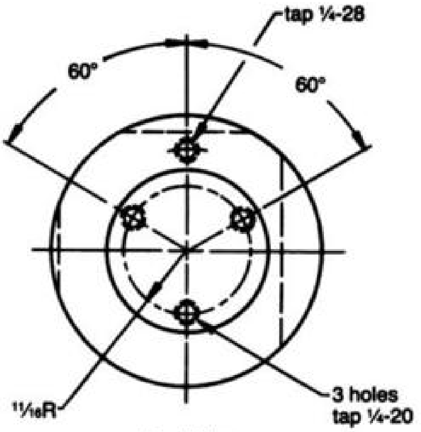
①


45°
45°
2 holes tap 10-32
3 holes tap 6-32
³⁹⁄₆₄R
60°
snug fit in gear cavity
⅛
1.437
.8752
1⅜
⁷⁄₁₆

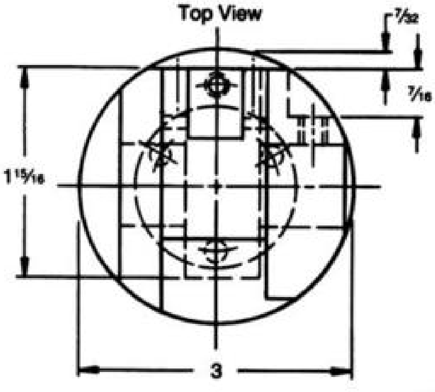
⑤


⁷⁄₁₆
4 holes tap 4-40
⅜
¼
1¹⁄₃₂
1¾
.875
tap ⁵⁄₁₆-18
¹³⁄₁₆
⅜
No. 28 drill
¼
⅜
⅝
¹³⁄₁₆
¼ .625 ¼
tap 6-32
2½

Top View

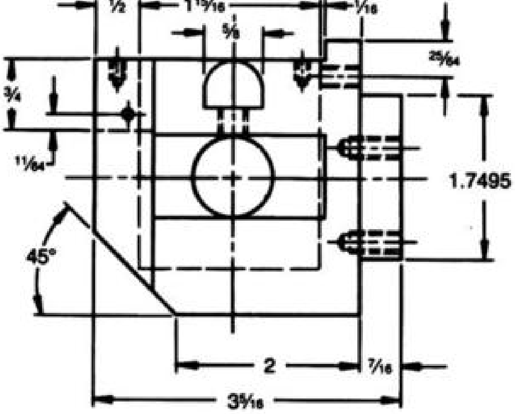

tap ¼-28
60°
60°
¹¹⁄₁₆R
3 holes tap ¼-20

Back View

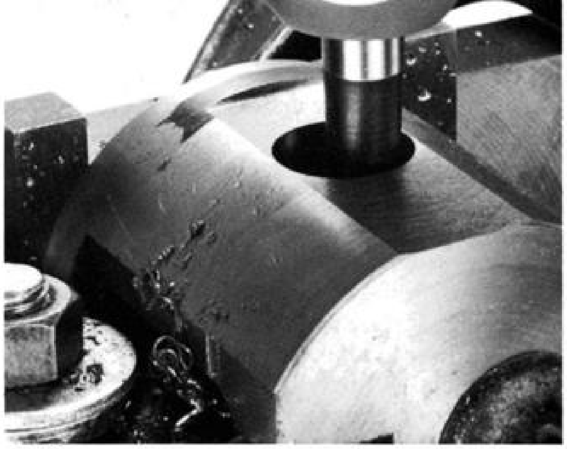

⁷⁄₃₂
⁷⁄₁₆
1¹⁵⁄₁₆
3

Front View

② BODY


1.375
½
1¹⁵⁄₁₆
¹⁄₁₆
⅝
²⁵⁄₆₄
¾
¹¹⁄₆₄
1.7495
45°
2
⁷⁄₁₆
3⁵⁄₁₆

Side View



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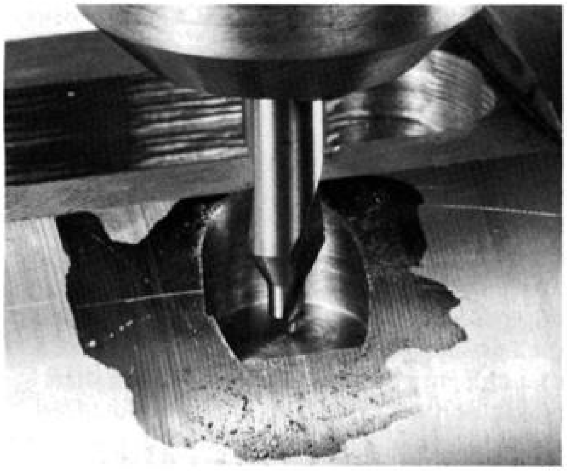
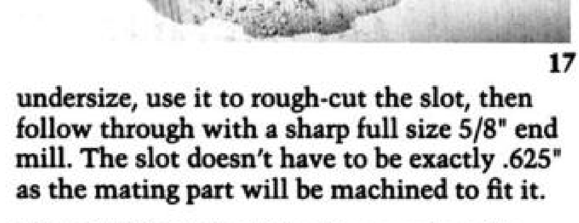


17

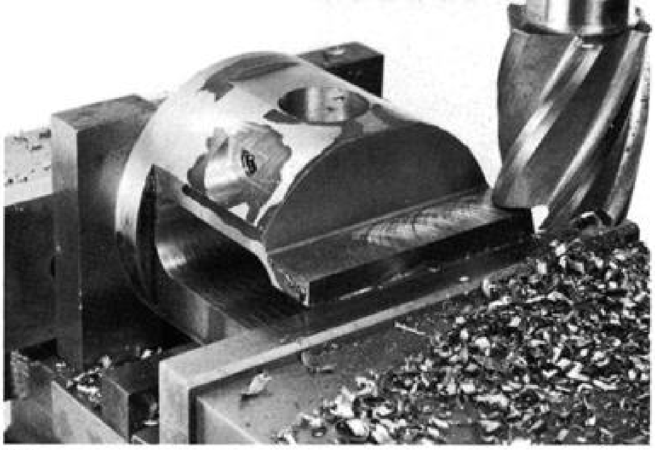
undersize, use it to rough-cut the slot, then follow through with a sharp full size 5/8" end mill. The slot doesn't have to be exactly .625" as the mating part will be machined to fit it.

Photo 15 illustrates the setup employed to locate the spindle hole. The hole should be exactly on the center line of the major body diameter and exactly 1.375" from the shoulder face on the back end of the body where an edge finder is making contact. As the spindle hole extends completely through the body, be sure to leave enough clearance space on the supports beneath. To start the hole, center drill it first, then follow through with a 1/4", 1/2", 3/4" or 13/16" drill. Finish bore the hole to .875" (Photo 16).



⑮

60°
60°
3 holes
1/4" dia.
11/16R
2 1/4
1/4
3/32
1.749
3/16



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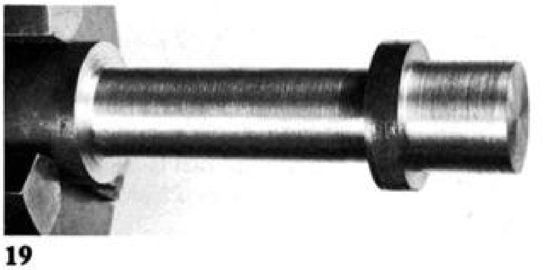

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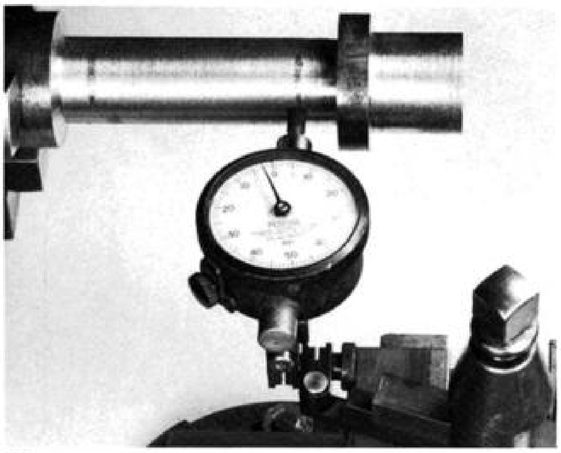

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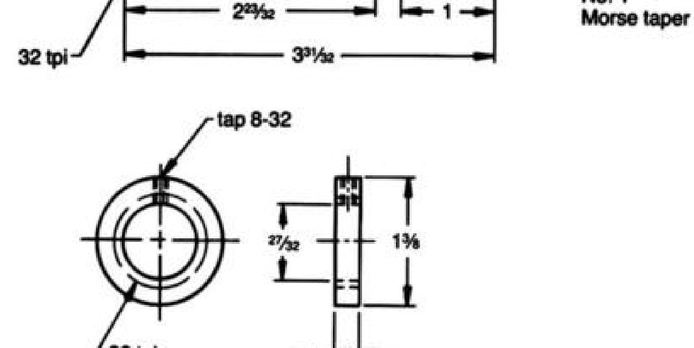
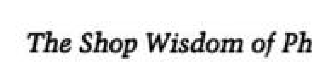


2 flats
90° apart
3/8
29/32
1/4
9/32
1"-10 thread
or to fit your
chucks
.875
25/64
.475
1 3/8
No. 1
Morse taper
2 23/32
1
3 31/32
32 tpi



tap 8-32
27/32
1 3/8
32 tpi
1/4

The spindle locking bolt is situated on the curved surface of the body (Photo 17). Therefore, it's necessary to mill a flat before drilling and tapping the hole. If you have an end mill of the proper size, it's possible to feed the cutter down from a vertical position; otherwise, form the flat by bringing in the cutter from the side.

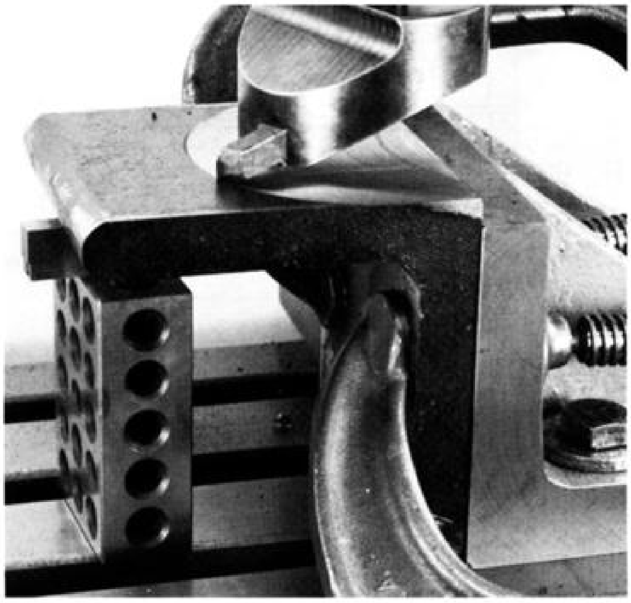
Photo 18 shows how the divider body was held while machining the pair of steps on its outer end. If you wish to mill a bevel on the lower outer end of the body (optional) this process would be next.

Because I have a 6" Atlas lathe, I machined the spindle nose with a 1" x 10 thread to fit the chucks of that lathe. If you have a small lathe, it's advantageous to thread the spindle to match your machine. Rough out the spindle, leaving it about 1/32" oversize (Photo 19). Do not support or center drill the outer end with the tailstock while doing this work. By removing most of the excess metal from the shaft, internal strains have been relieved. If the end had been center drilled at the beginning, it now would probably be off-center. Now finish face off the end of the shaft and carefully center drill it. Use an 11/32" drill to drill a hole in the spindle to a depth of 4-1/4". Finally, enlarge the hole with a 25/32" drill. By increasing the diameter of the hole to 25/32", we have eliminated some of the depth needed to bore out the spindle nose for a No. 1 Morse taper. Roughly, the taper per foot for a Morse taper is 5/8"; however, this angle varies from one size Morse taper to the next. A No. 1 taper increases in diameter by .104" in a distance of 2-3/16".

Not having a taper attachment for my lathe, I used the compound slide to bore the taper. Photo 20 illustrates the method I employed to arrive at the correct angle. First, set the compound at an angle of about 1-1/2°. Mark off a distance of 2-3/16" on the spindle. Set a dial indicator on the center line of the shaft and in line with one of the marks. Now feed the compound along the workpiece until it has

21

22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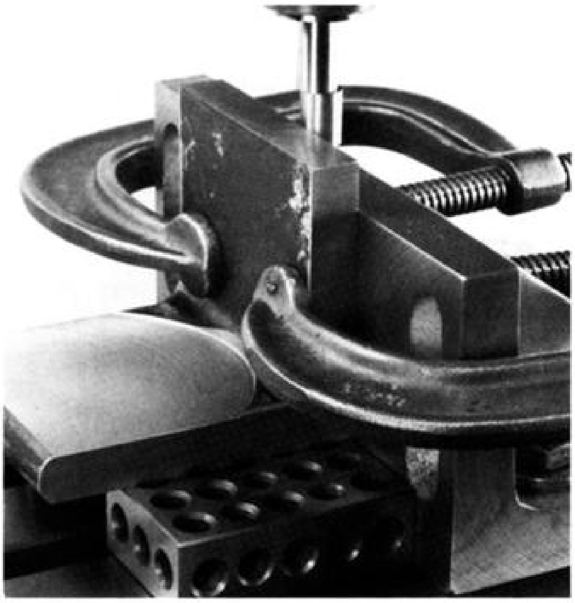
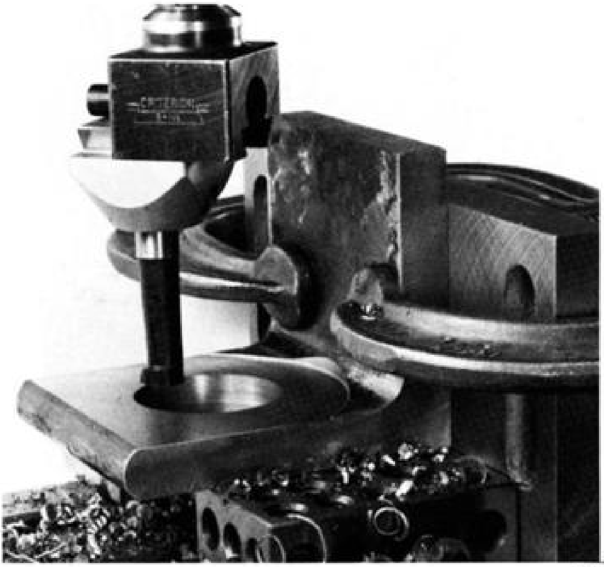

24

traveled exactly 2.187". The dial indicator should show a change of .052" in that distance. Readjust the compound angle until you get that reading. Use a boring bar just small enough to enter the hole without hitting the sides.

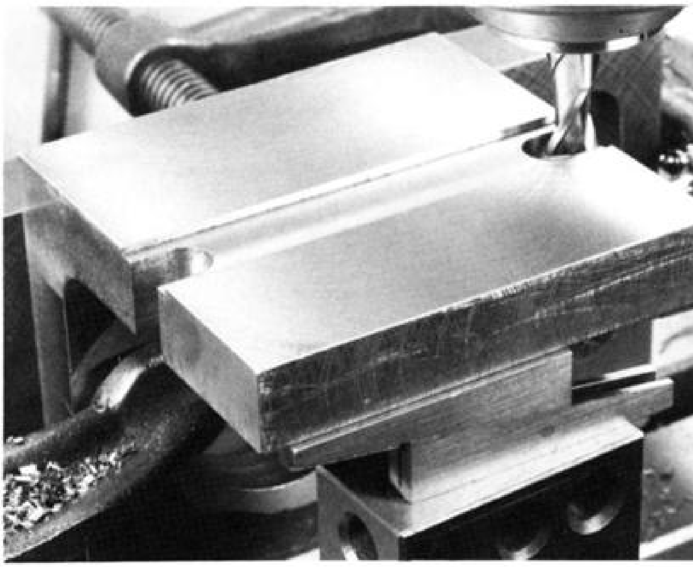
The length of the taper to be bored is about 1-5/8", so use a boring bar that is about 1-3/4" long for safety. Set your cutting tool on dead center and proceed to machine the taper. Take very light cuts. Chattering can be reduced by using a slower spindle speed. When the outer end of the bore approaches .475", it's time to chalk up a No. 1 Morse taper center. Insert it in the hole with a twisting motion, remove it, and examine its surface to see where the chalk has been disturbed. You may have to carefully readjust the compound to get an even fit along the center of the taper. After completing the taper, set the compound to 30° and machine a small bevel in the end for a tailstock support (Photo 21). Now cut the nose threads and finish the shaft diameter – it should be about .00025" smaller than the spindle bore in the divider body. Now cut 32 tpi at the back end of the spindle (Photo 22). Note the V-groove at what will be the rear end of the spindle. Position your cutoff tool so that one-half of this bevel will remain on the spindle when completed.

Construction of the end-play adjusting collar that screws over the back end of the spindle is so simple that no explanation is needed, except to mention that the locking setscrew in its rim should have a soft aluminum or brass pad between it and the threads on the spindle.

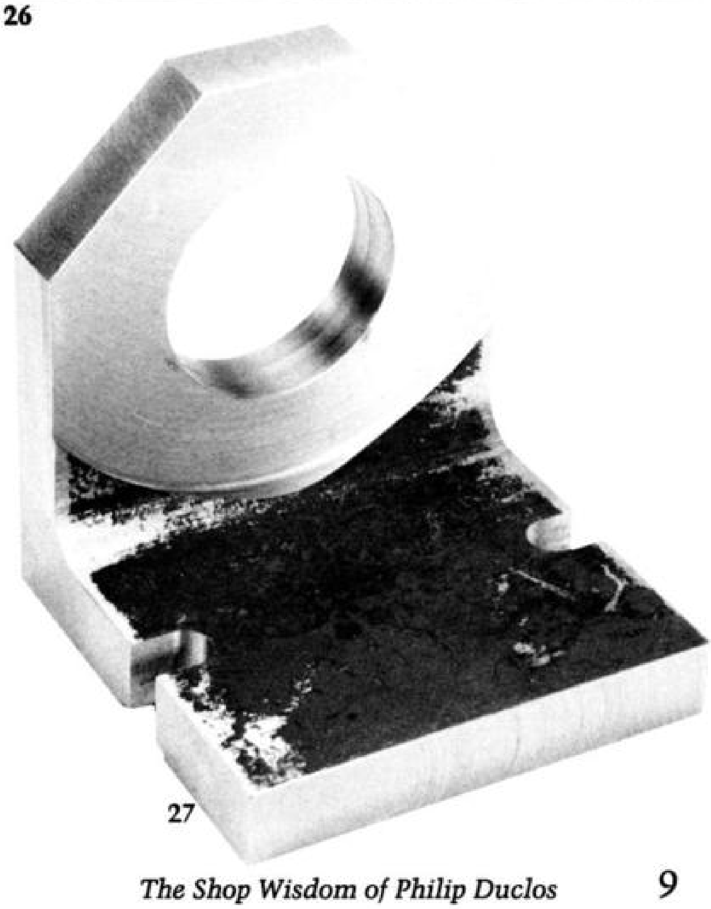
For a change of scenery, begin work on the angle plate. Photo 23 shows one method of clamping the work for machining. Use husky C-clamps while squaring the piece to a true 90° angle on both outside faces. Also mill the two side edges, bringing them to the correct length. Now mount the work as in Photo 24. Fly cut one surface of the inner side as shown. The 1-3/4" hole about to be bored in this machined area is situated in the center of the plate in one direction and exactly 2.250" away from bottom of the base surface; the use of an edge finder is important. Upon arriving at the correct location, be sure to lock the mill table in both directions. Rough drill the hole and



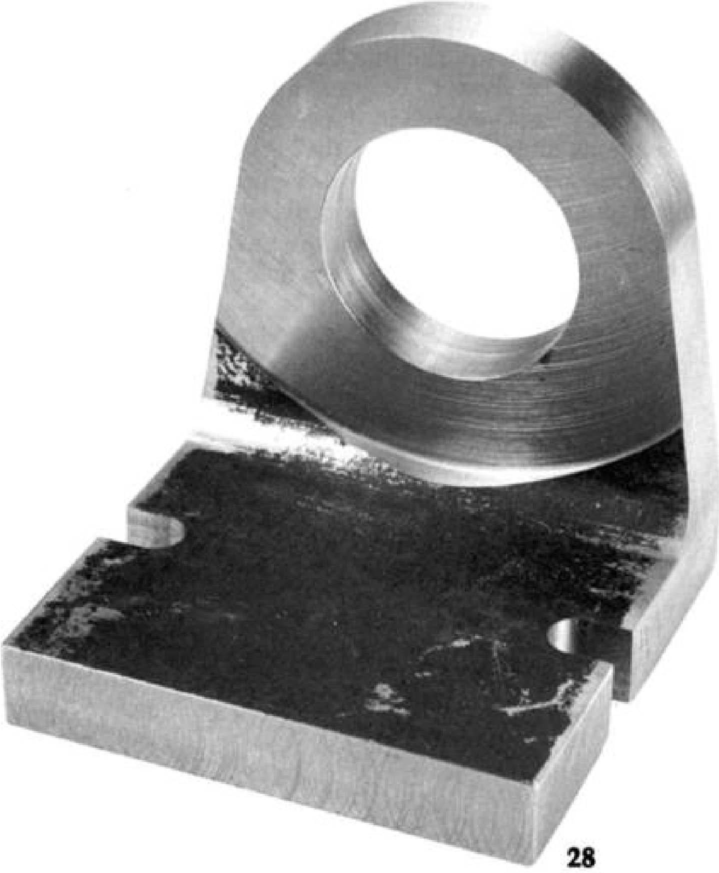
25



26



27

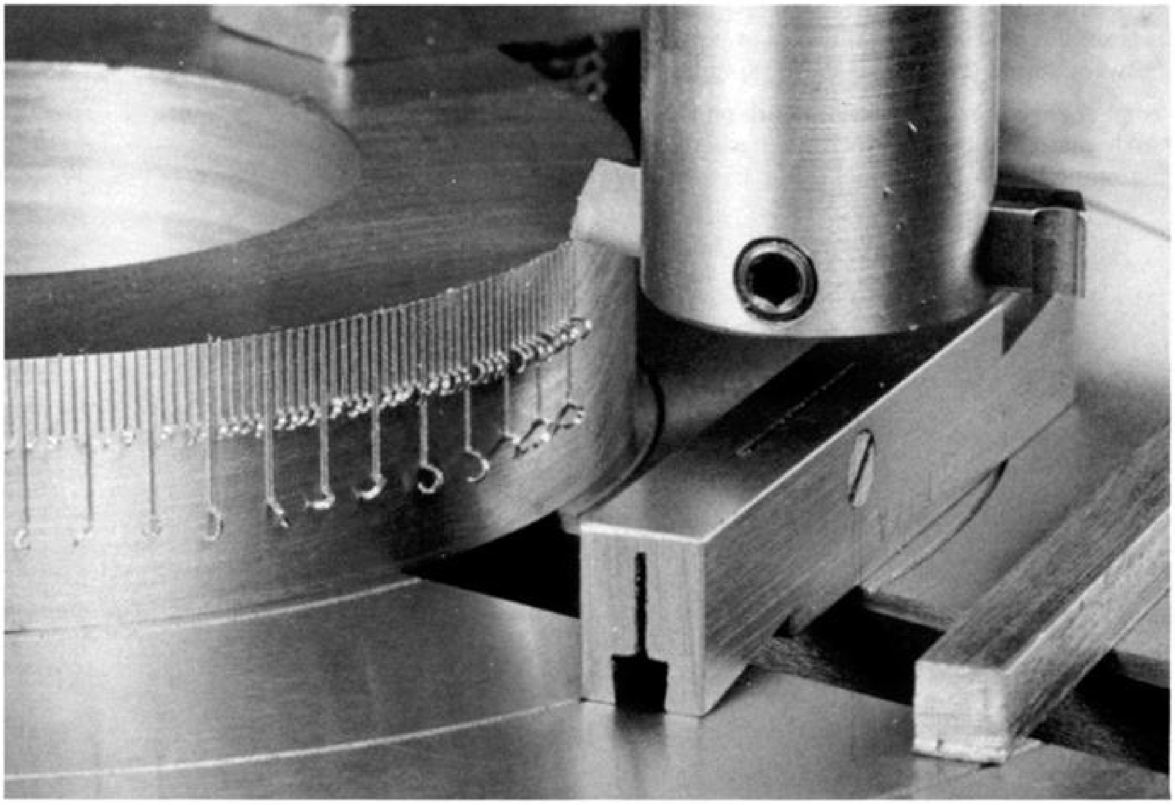


28

finally bore it out to a snug slip-fit for the divider body (Photo 25).

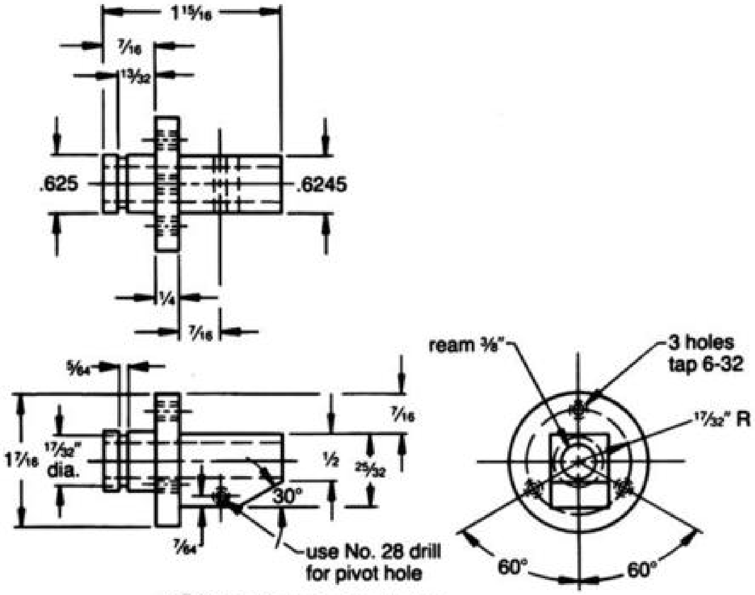
To equip the dividing head with locating lugs that fit the T-slots of a milling machine table, the angle plate must be positioned, bottom surface up, as in Photo 26. A groove about 1/16" deep is machined the length of the base; this slot will position the two lugs. Naturally, the workpiece must be perfectly aligned with the longitudinal travel of the mill table. I made a groove .625" wide to match the T-slots of my mill. This slot should be exactly centered below the center line of the divider spindle; that would be 1.375" plus the thickness of the angle plate where the 1-3/4" hole has just been bored. Again use an edge finder to determine this location.

To complete the angle plate, two options are available. First, as in Photo 27, merely bevel off the vertical corners. Second option (Photo 28), machine a round arch with the aid of a rotary table. The addition of degree marks on the arch is not absolutely essential, but on occasion they do come in handy. To scribe degree lines (Photo 29), the angle plate should be perfectly centered on a rotary table mounted on a vertical milling machine, which will be used as a glorified arbor press. The scribing bit is placed in a husky boring bar and the bar in turn is held in the mill spindle. Grind your



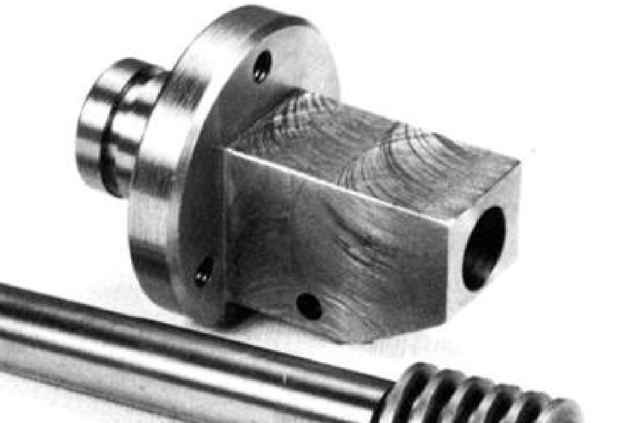
scribing bit similar to a 60° threading tool; however, it needs only a small amount of side clearance to the cutting edge. Excessive clearance will weaken the sharp point and it may crumble under pressure. The depth of the scribed lines is about .005". Length of the lines are controlled by inserting suitable stop blocks below the boring bar, as in Photo 29. When the angle plate is completed, your dividing head should resemble the one in Photo 30.

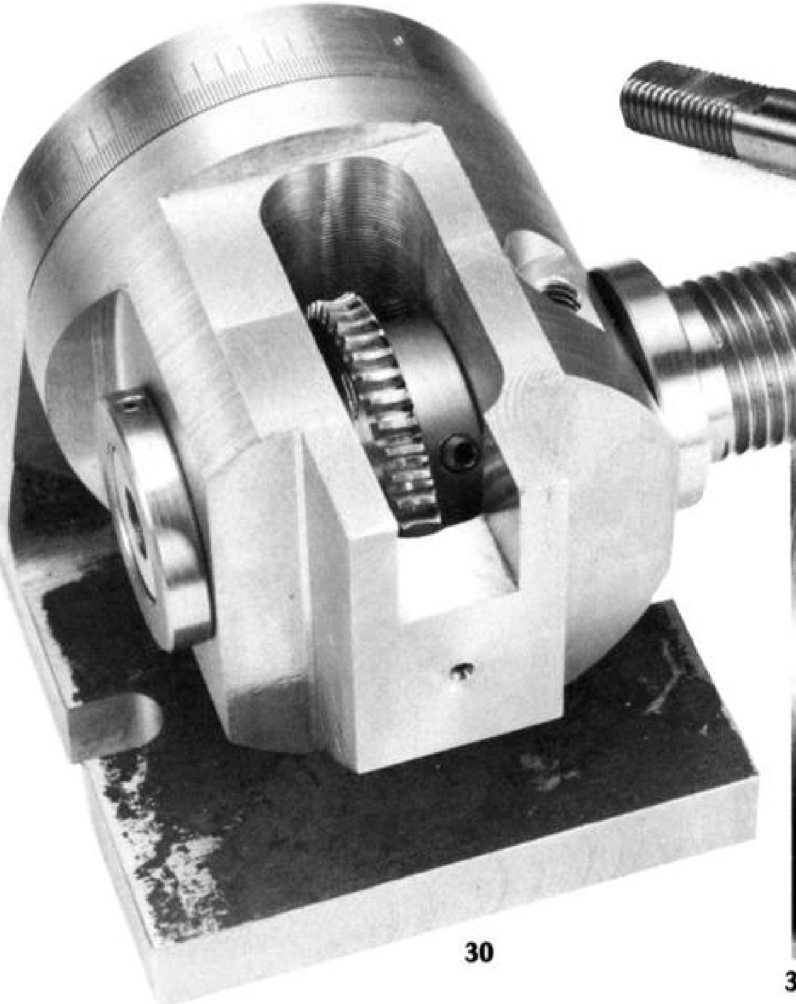
The next items to fabricate for your dividing head will be the worm shaft housing and the worm drive shaft (Photo 31). Note the ball thrust bearing pressed into the end of the shaft (optional). Begin with the worm shaft housing as in Photo 32. Observe the V-shaped groove on the large diameter; its merits become obvious when milling the rectangular portion of the housing (Photo 33). After the first and deepest flat has been milled to the bottom of the V-groove, set the graduated dial on your mill table to zero.


1 15/16
7/16
13/32
.625
.6245
1/4
7/16
5/64
1 7/16
17/32" dia.
7/16
1/2
25/32
30°
7/64
use No. 28 drill for pivot hole
ream 3/8"
3 holes tap 6-32
17/32" R
60°
60°

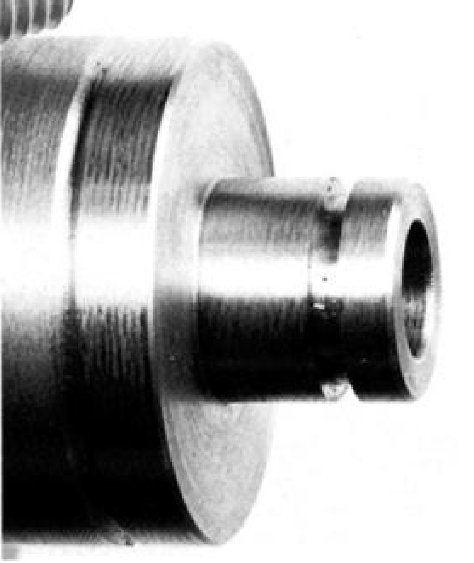
③ WORM SHAFT HOUSING

31

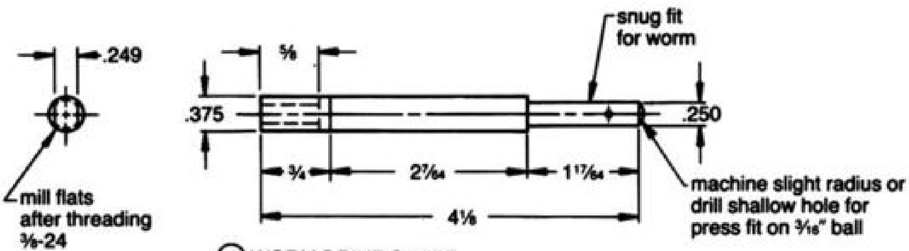




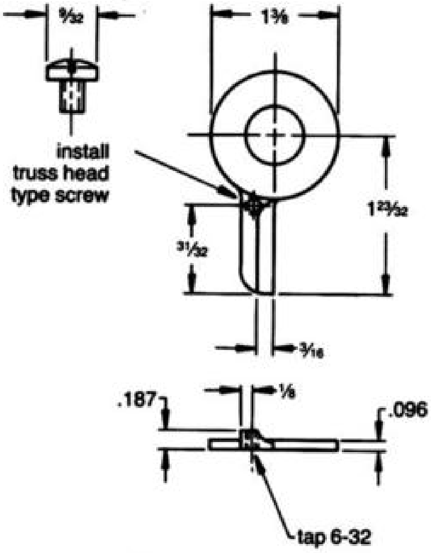
30



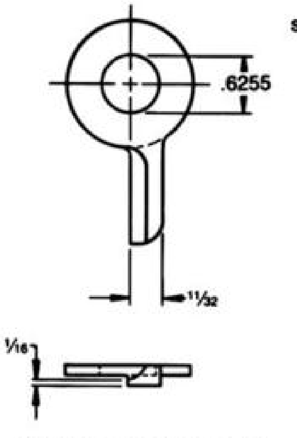
32


.249
mill flats
after threading
3/8-24
5/8
.375
snug fit
for worm
.250
3/4
2 7/64
1 17/64
4 1/8
machine slight radius or
drill shallow hole for
press fit on 3/16" ball

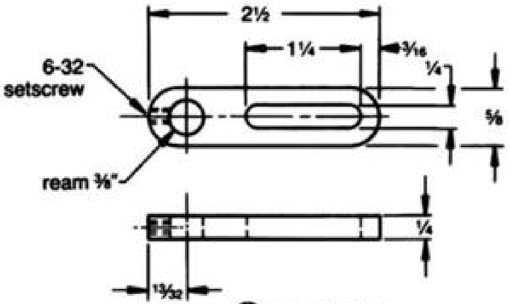
④ WORM DRIVE SHAFT


9/32
1 3/8
install
truss head
type screw
1 23/32
31/32
3/16
.187
1/8
.096
tap 6-32

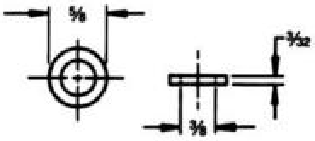
⑦ LOWER SECTOR ARM


.6255
11/32
1/16

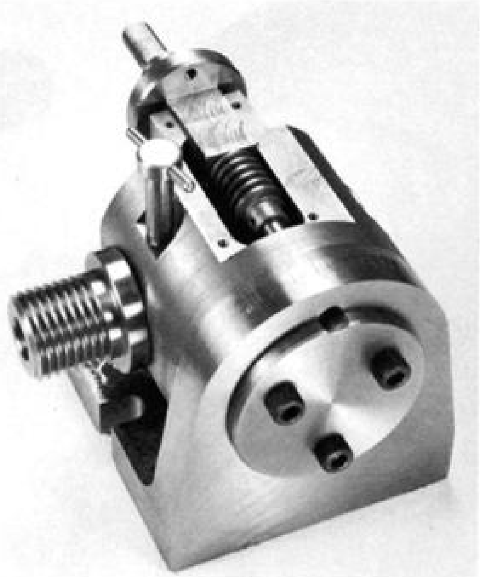
⑧ UPPER SECTOR ARM


2 1/2
1 1/4
3/16
1/4
6-32
setscrew
5/8
ream 3/8"
1/4
13/32

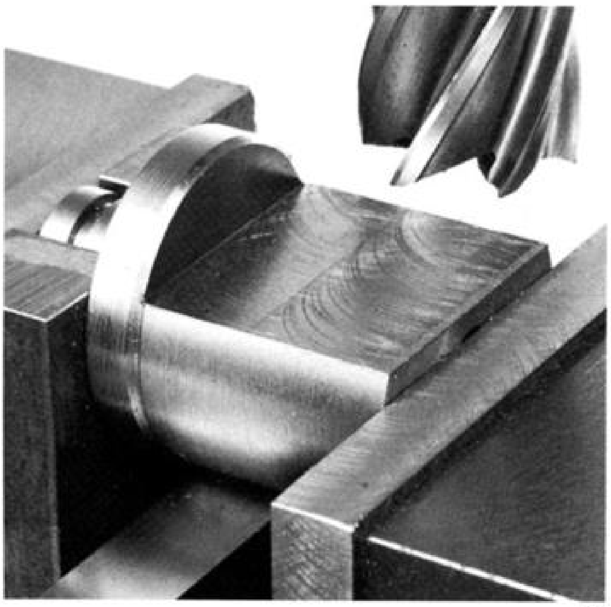
⑨ CRANK ARM



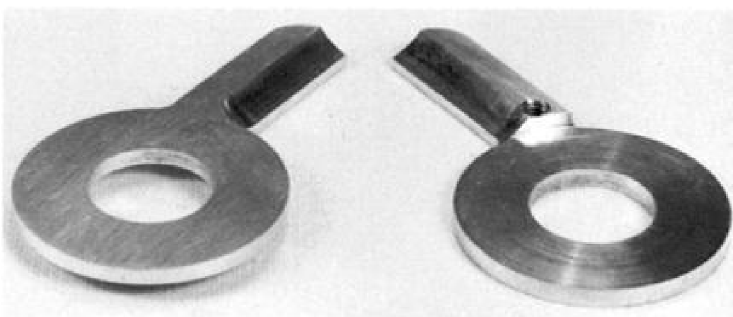
⑩ WASHER



34



33



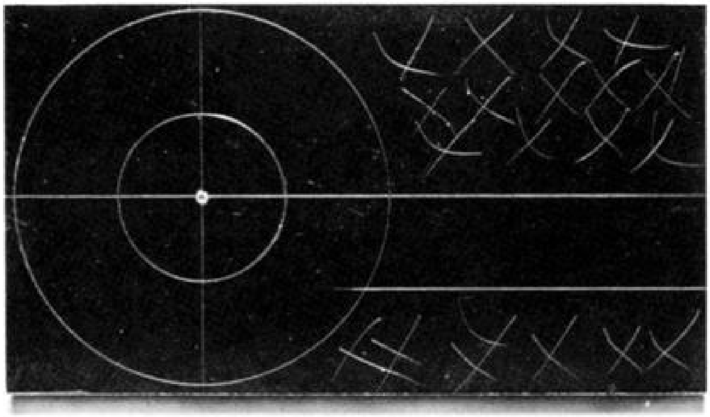
35

machine a flat on the top surface. This flat is not as deep as the first one, so check the plans. As you mill, move the cutter towards the V-groove until the zero setting on the dial is reached. Now reposition the piece so the flats just machined are in a vertical position, using a precision square to set them. The third and fourth flats to be machined should be fairly equidistant to the center line of the workpiece. They are the ones that should fit snugly into the 5/8" slot in the body (Photo 34). To estimate how much to mill from each side, first mike the round diameter of the body. Subtract the width of the slot in the divider body (presumably .625") and divide the difference by 2. That would be the amount needed to lower the end mill from a touch-scratch position on the top curved portion of the workpiece. Set the quill's graduated dial to zero. Gradually mill down to the desired depth. Once more, reposition the surface just machined face down in the vise. Readjust the height of the parallels under the workpiece so the end mill won't plow into the vise jaws during the machining. Make sure the work is seated solidly on the parallels.

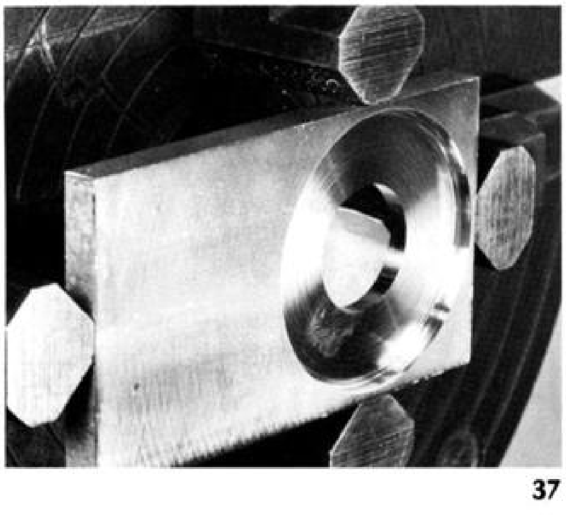
Again set the end mill to a touch-scratch position and gradually mill down – but stop when about .010" short of reaching the required depth. Remove the work from the vise and mike across the two flats being machined. Also carefully measure the width of the slot in the divider body. This can be done by sliding an adjustable parallel into the slot for a snug fit and then miking the parallel. The difference between the two readings is the amount remaining to be milled off the flat. Again set the work in the vise with the same surface up. Seat it solidly on the supporting parallels. Machine off the required amount. Finally, mill the 30° bevel on the lower end portion of the housing.

The worm drive shaft needs little explanation except to mention that I used a 3/32" spring "dowel" pin through the worm hub and shaft to secure it properly.

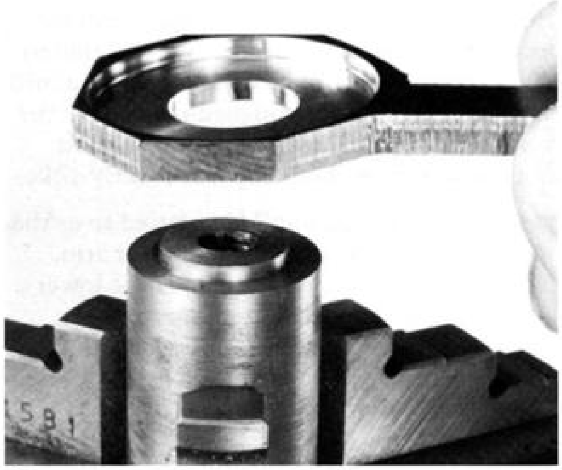
The dividing segment (or sector) arms are rather easily constructed (Photo 35). They're usually made of brass or bronze, but lacking that type of metal, I made mine out of



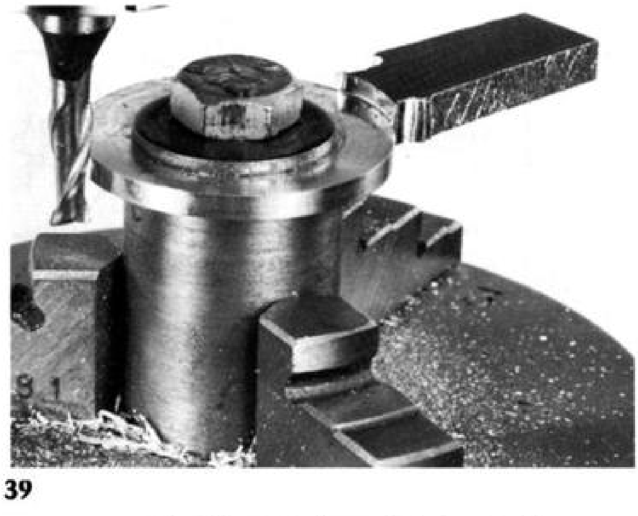
36



37



38



39

tempered aluminum plate; steel also could be used. Lay out two identical 3/16" thick plates similar to the one in Photo 36. Use a four-jaw chuck on your lathe and adjust it until the center mark in the layout runs fairly true. Drill and then bore a hole through to a diameter of .6255". Now counterbore to a depth that is two or three thousandths less than half the thickness of the plate (Photo 37). The diameter of the counterbore should be 1/32" oversize – 1-13/32". Repeat the process for the second arm. Rough cut the outlines of the segment arms with a hacksaw (Photo 38). If you don't have a rotary table, the arms can be finished with a file. If you use a rotary table, it's first necessary to machine a stub arbor in your lathe. Drill and tap a 5/16-18 hole in the arbor center as in Photo 38.

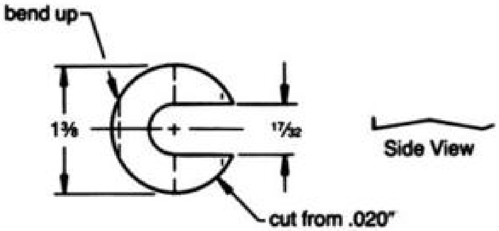
With the arbor still in place, remove the chuck from your lathe and clamp it vertically onto the rotary table; with the aid of a dial indicator, center it perfectly with the rotation of the table. If you are unable to clamp the chuck properly onto the rotary table, then remove the stub arbor from the chuck. Clamp the arbor vertically in a small vise and then clamp the vise onto the rotary table. Now mill the circular portion with a 3/16" end mill (Photo 39). Remove the workpiece, clamp it in a mill vise and machine the roughed-out arm to the correct width and length. Up to this point, both sector arms should appear exactly alike.

Henceforth, one arm will be referred to as the lower arm and the other as the upper arm. The one illustrated in Photo 40 is the lower arm. Note the threaded hole situated very close to the inner shoulder of the arm; this is for the sector arm locking screw. I used a 1/2" ball end mill to machine a slope as indicated in Photo 40. A bevel cutter could also be used for the job; otherwise, file the slope by hand.

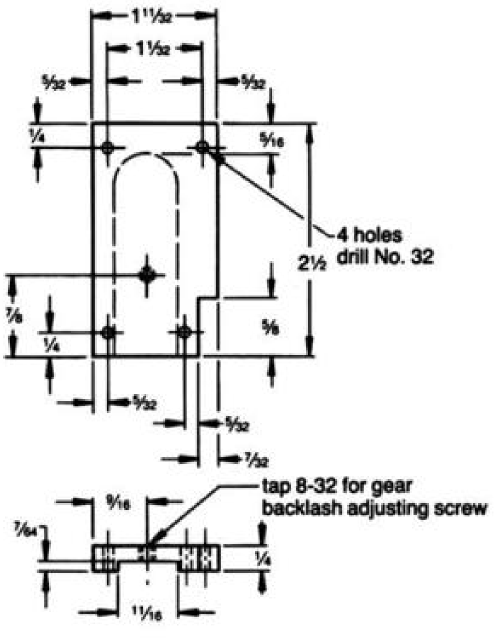
The upper arm is finished in the same manner except that the sloping portion on the arm is milled on the opposite side of the arm. Refer to Photo 35.

Note that in Photo 41 the flat-faced end play adjusting screw is contacting the ball tip on the worm drive shaft. Also note how the bottom surface of the gear cover plate has been milled out. The T-shaped spindle locking lever should have an aluminum or brass disk pad inserted between it and the spindle.

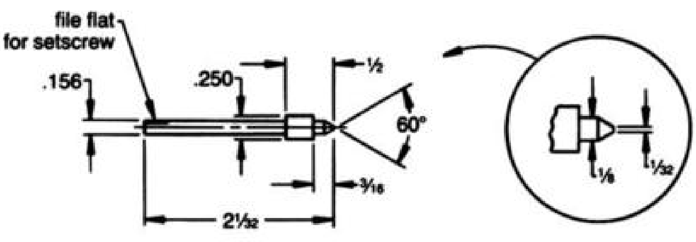
A rectangular block of aluminum was employed to form the dog driver (Photo 42); it had been rough-milled prior to chucking in the lathe, then bored and threaded to fit the divider spindle (Photo 43).


bend up
1⅜
17/32
Side View
cut from .020" sheet metal

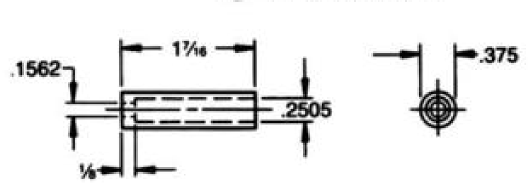
⑬ INDEX SPRING CLIP

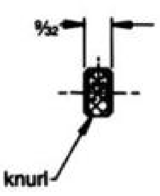

1 11/32
1 1/32
5/32
5/32
1/4
5/16
4 holes drill No. 32
2½
7/8
1/4
5/8
5/32
5/32
7/32
tap 8-32 for gear backlash adjusting screw
9/16
7/64
1/4
11/16

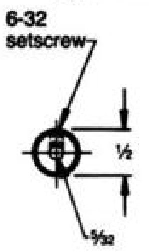
⑭ GEAR COVER

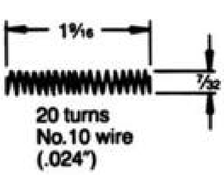

file flat for setscrew
.156
.250
½
60°
3/16
2 1/32
1/8
1/32

⑫ INDEX CRANKPIN


.1562
1 7/16
.2505
1/8
.375

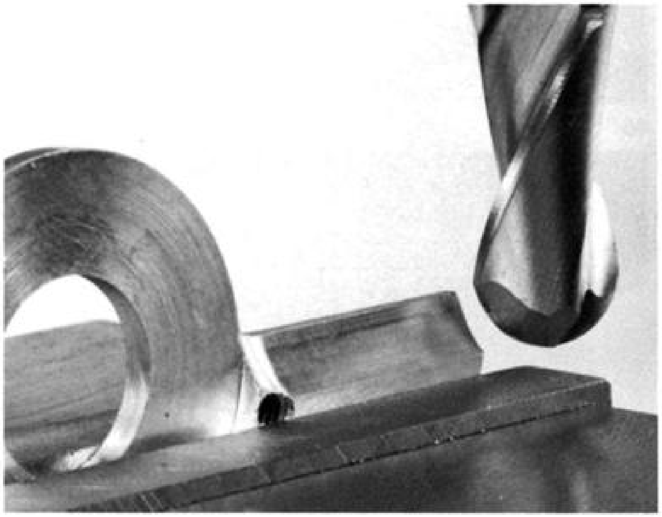



6-32 setscrew
½
5/32

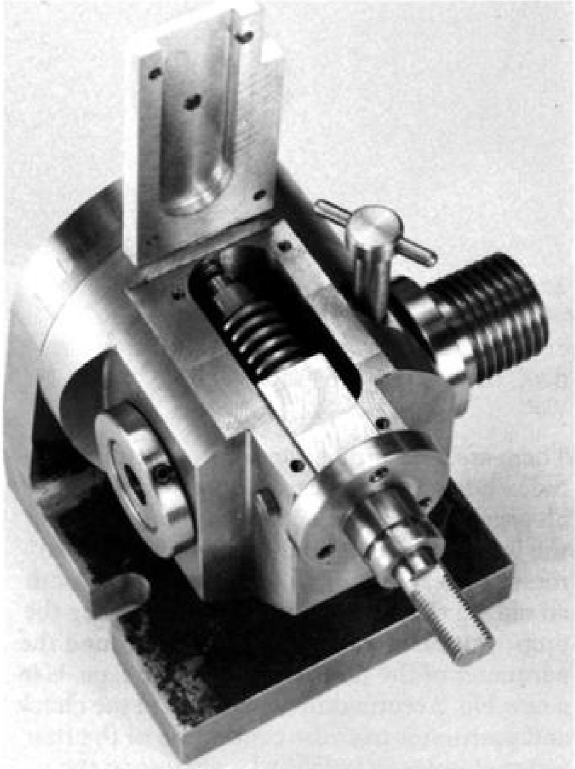

1 5/16
7/32
20 turns
No.10 wire
(.024")

Machining of the three index plates is next. I had a piece of 3-7/16" round steel bar stock so had no trouble slicing off (with the aid of a steel cutting band saw) three disks slightly over 1/4" thick. These disks could also be made from 1/4" flat steel plate or aluminum. Photo 44 illustrates one method of locating a disk in the chuck preparatory to facing it off. With a lead hammer, tap the disk snugly against the parallels and tighten the jaws. Be sure to remove the parallels before turning on the machine; they'll fly out for sure – very dangerous! Face one side of the disk, then reverse the piece in the chuck. Again tap the disk against the parallels, remove them, and face the piece to a thickness of 3/16". Now center drill, drill and bore the .6255" hole in the disk. Repeat this procedure on the other two plates.

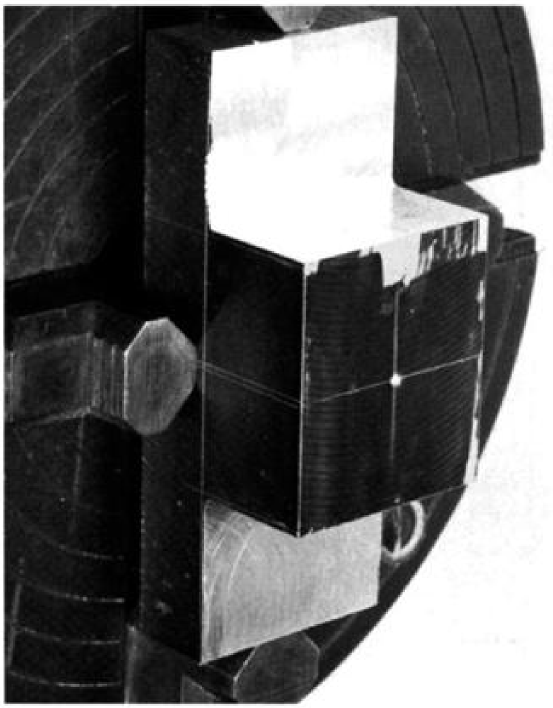
To true up the outside diameter of the disks, chuck up a short piece of rod about 1-1/4" in diameter, or larger (Photo 45). Machine a stub



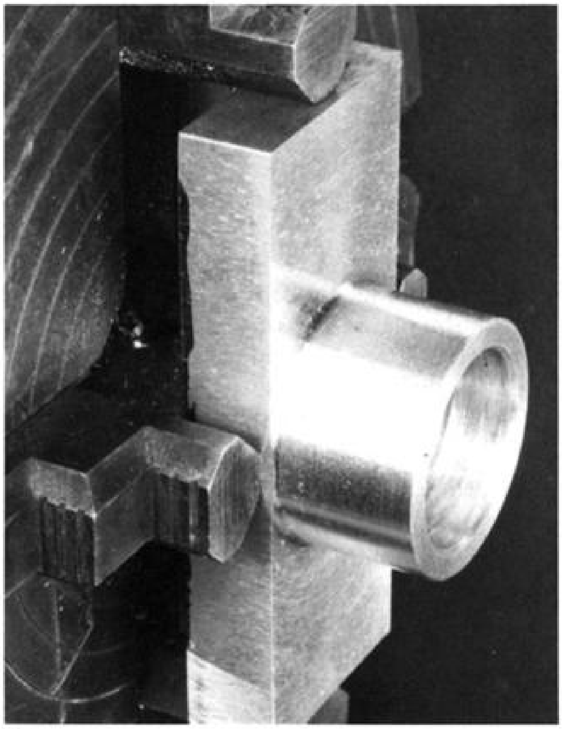
40



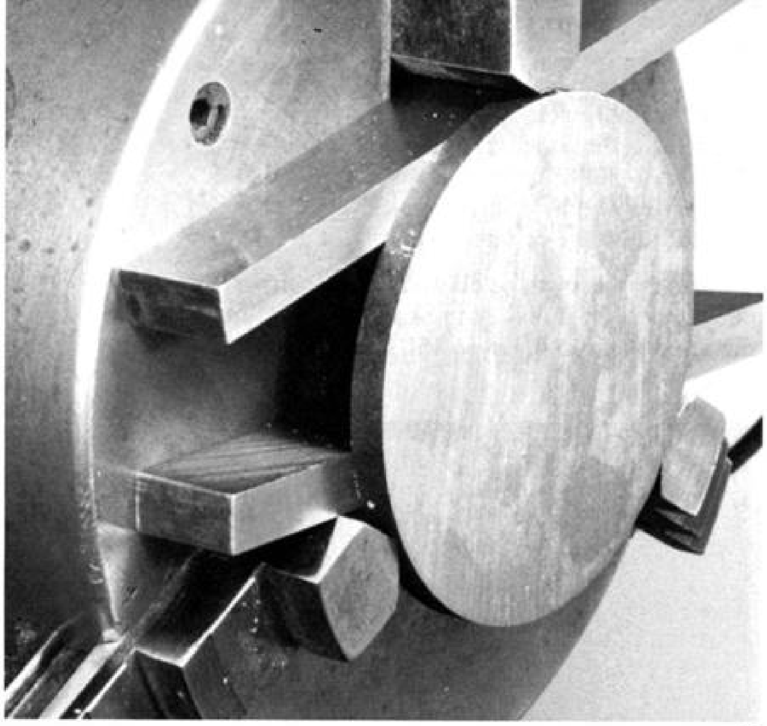
41



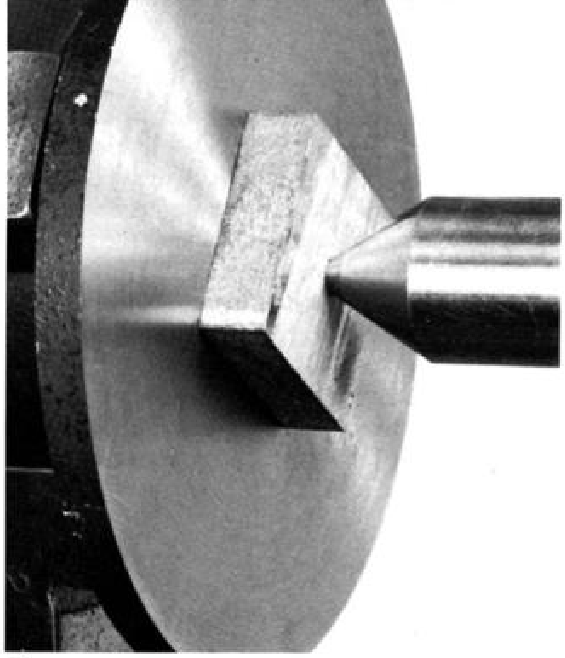
42



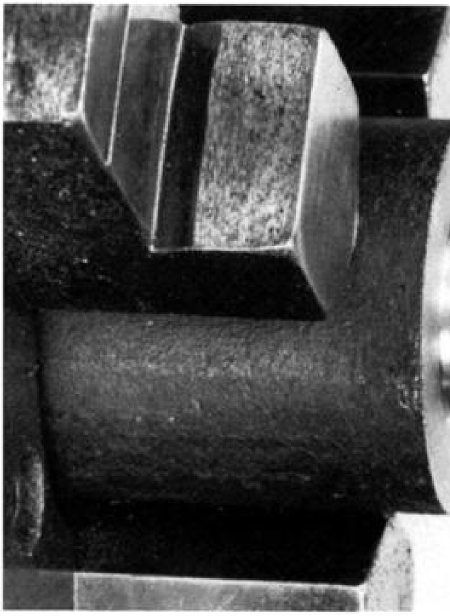
43



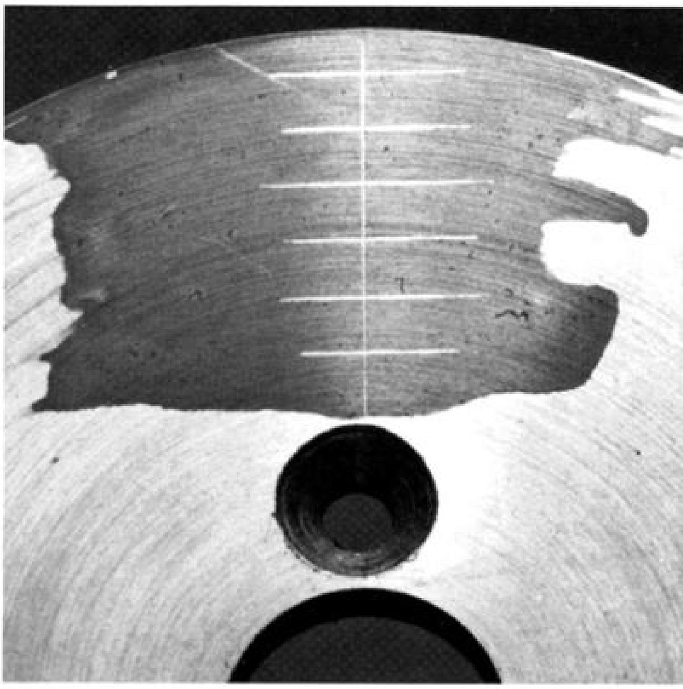
44



46



45

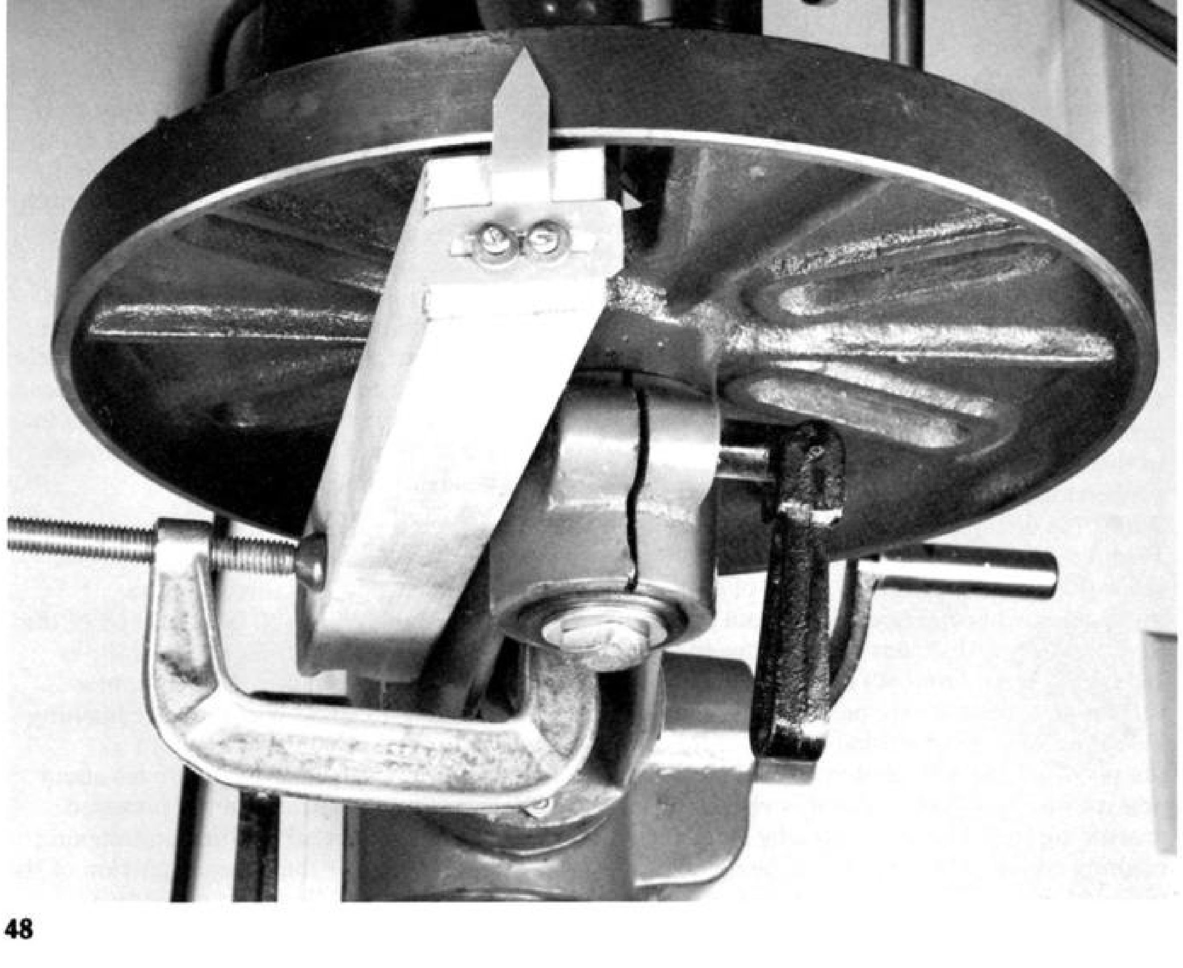


47

arbor about 5/32" long for a snug fit in the hole of the plates. Now use a scrap piece of flat metal (Photo 46), and center drill it. Mount a disk on the stub arbor; bring the tailstock center to bear tightly against the pad. Avoid slippage of the workpiece by taking very light cuts on its rim to true it up.

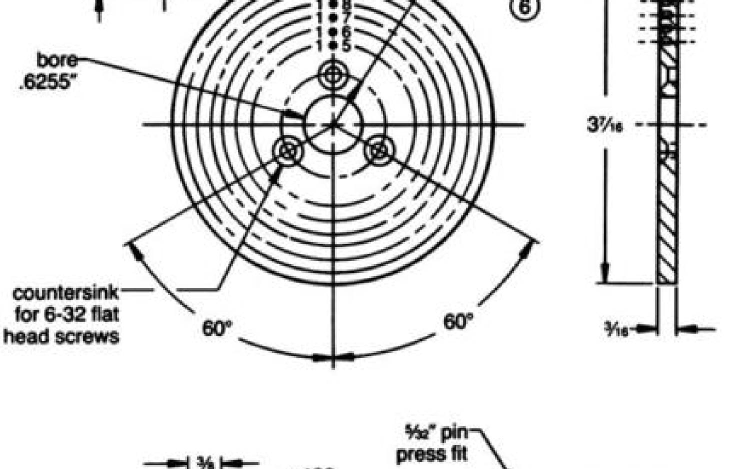
Carefully lay out and then drill the three equidistant bolt holes in one of the plates. Use this disk as a master to duplicate the three holes in the other plates. Lay out the center lines for each series of index holes. Each disk will have six series (Photo 47). The center lines are identical in all three plates. The first center line is 1/8" from the outer rim of the disk, the rest are 9/64" apart.

There are a least three options for drilling the index holes. Refer back to Photos A, B, and C on page 2. In Photo A, it's possible to center the work with a dial indicator on an 8" or 10" rotary table. Cut out an oversize pointer from an old tin can. The paper strip, containing the proper number of divisions, is held around the perimeter of the table with adhesive tape. Use a new No. 2 center drill (or smaller) in the chuck and position it over the center line of the first series of holes to be drilled – nearest to the

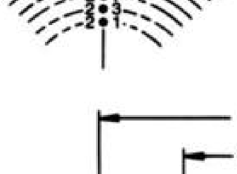


48

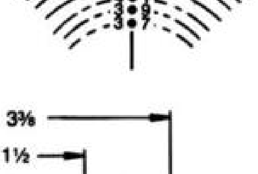
NO. 1 DIVIDING HOLE PLATE

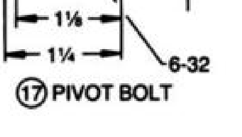

9⁄64 typ.
1⁄8
17⁄32" R
2 0
1 9
1 8
1 7
1 6
1 5
⑥
bore
.6255"
countersink
for 6-32 flat
head screws
60°
60°
37⁄16
3⁄16

NO. 2 DIVIDING HOLE PLATE

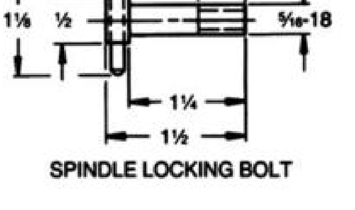

3 3
3 1
2 9
2 7
2 3
2 1

NO. 3 DIVIDING HOLE PLATE

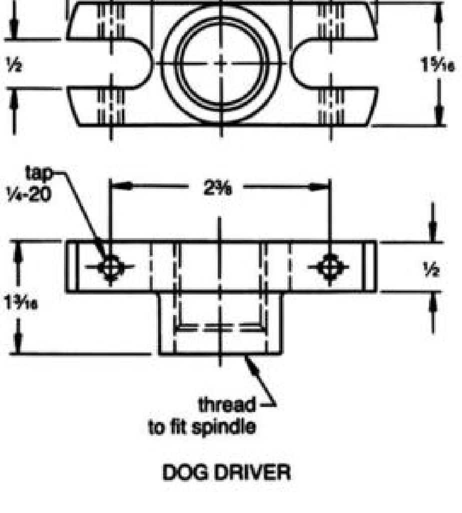

4 9
4 7
4 3
4 1
3 9
3 7


3⁄8
.138
11⁄8
11⁄4
6-32

⑰ PIVOT BOLT


5⁄32" pin
press fit
11⁄8
1⁄2
1⁄2
5⁄16-18
11⁄4
11⁄2

SPINDLE LOCKING BOLT

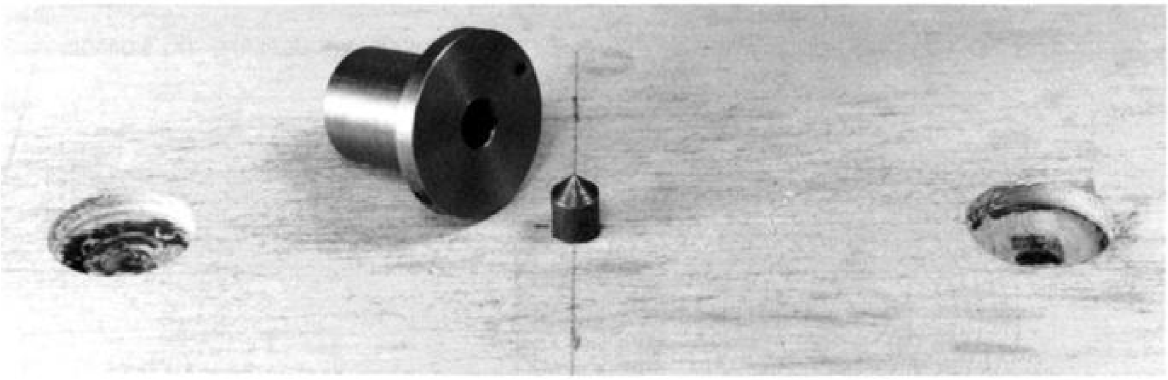

33⁄8
11⁄2
1⁄2
15⁄16
tap
1⁄4-20
23⁄8
1⁄2
13⁄16
thread
to fit spindle

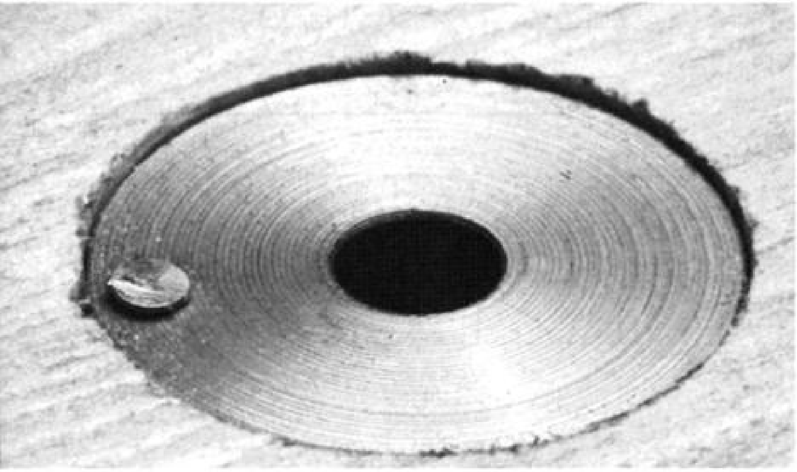
DOG DRIVER

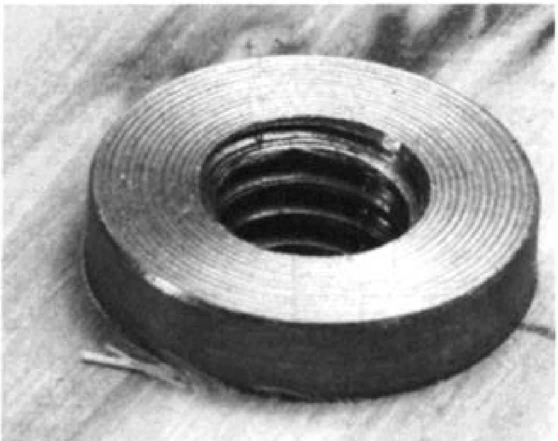
center of the plate. There will be 15 holes drilled around the disk at this location. The next higher will have 16 holes, then 17, 18, 19, and finally 20 holes nearest the rim of the plate. The second disk will have 21 holes nearest the center of the plate, then 23, 27, 29, 31, and 33 holes. The third disk will have 37 holes, 39, 41, 43, 47, and 49.

If a rotary table is not available, a drill press with a circular revolvable table will work just fine (Photo B). The setup is similar to the rotary table except for rigging a supporting arm for the pointer (Photo 48). What? No drill press with a circular table? Then we go to a drill press with a square table (Photo C). I used two pieces of 3/4" plywood, the bottom one being about 9 x 10"; the top rotating disk was roughed out to about 10" in diameter. Photo 49 is a close-up of the top surface of the square piece of plywood. A 15/64" hole has been drilled in the center of the plywood and a 1" section of 1/4" steel rod pressed into it; a short section is visible protruding from the wood. Nearby is a flanged bushing which, when placed in the upper plywood disk, will rotate around the rod. The two countersunk holes are for carriage bolts that will pass through the slots in your drill press table and thus hold the plywood firmly in place. The flanged bushing is machined from a piece of 1" round stock, overall length is 7/8". The flange thickness is 1/8" and the smaller OD of the bushing is .625". Run a 5/16-18 tap into the 1/4" hole starting from the small end of the bushing. Thread it to a depth of about 5/8"; do not thread completely through. The remaining portion of the hole should be a snug fit on the protruding pin in the base section. Drill a 1/16" hole through the flange near its outer edge.

Now drill and counterbore a hole in the center of the plywood disk. The hole should be a tight fit on the .625" diameter of the flanged bushing. Photo 50 is a close-up of the bottom surface of the disk. The bushing is pressed into place and a small nail or brad through the 1/16" hole will keep the bushing from turning in the plywood. Photo 51 illustrates how the bushing protrudes about 1/8" above the top surface of the plywood disk. During the actual drilling, an indexing plate is slipped over the exposed portion of the bushing and is held firmly in place by a washer and a 5/16-18 bolt that screws into the



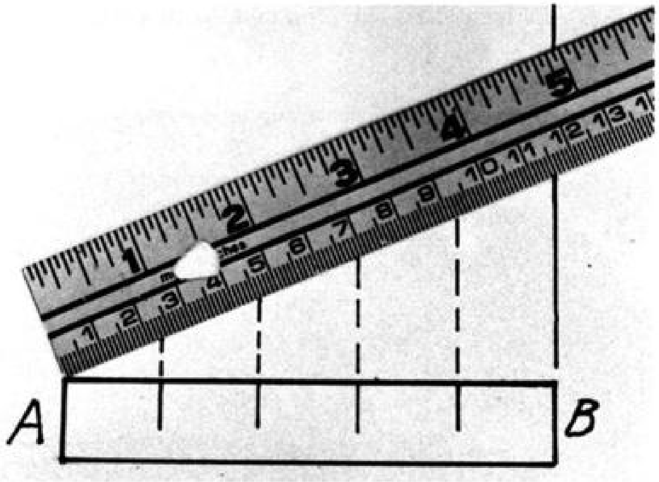




bushing. Photo 52 indicates a method of truing up the rim of the plywood disk. Chuck up an end mill and rotate the disk by hand against the revolving cutter. Take very light cuts and hold the disk tightly.

Now we come to the matter of laying out the proper divisions on the long paper strips that encircle the rotating table. Here's where the metric system really proves its worth. The example in Photo 53 will bear this out. The smallest divisions on the metric side of the rule represent 1 mm (millimeter). The space between its numbered divisions (1, 2, 3, 4, etc.) represent one centimeter, or 10 mm. The distance A to B represents the length of an imaginary paper strip. Let's assume we wanted to divide that length into, say, five equal divisions. The exact tip of the rule must always line up with the end of the strip at position A. Now tilt the rule to an angle of 25° or 30° (not critical). In this instance, the length along the rule to the vertical line at B is 115 mm. As we are seeking five equal divisions, divide 115 by 5 = 23 mm. Use a T-square in a vertical position with the T-portion of the square held firmly against the lower edge of the drawing board. Start at position A and count off 23 mm. Line up a vertical edge of the T-square at 23 mm and from that position draw a fine line onto the paper strip. Stop drawing the line when it's about 2/3 of the way down on the strip. Later on, when drawing the real strips of paper, if you follow this procedure, it's possible to draw two different sets of divisions on each side of the paper. To draw the next line simply add 23 mm to each succeeding line to be drawn – that is 46, 69, 92 mm.

Let's assume that when we first placed the metric rule at an angle, the vertical line at B intersected the rule at 118 mm. Since 5 will not divide evenly into that number, it's necessary to either lower or increase the angle slightly until a number is reached that is exactly divisible by 5. We could increase the angle of the rule until the 12 centimeter (120 mm) mark is in line at B; or we could lower the rule angle to the 11 centimeter (110 mm) mark; either one is divisible by 5.



53

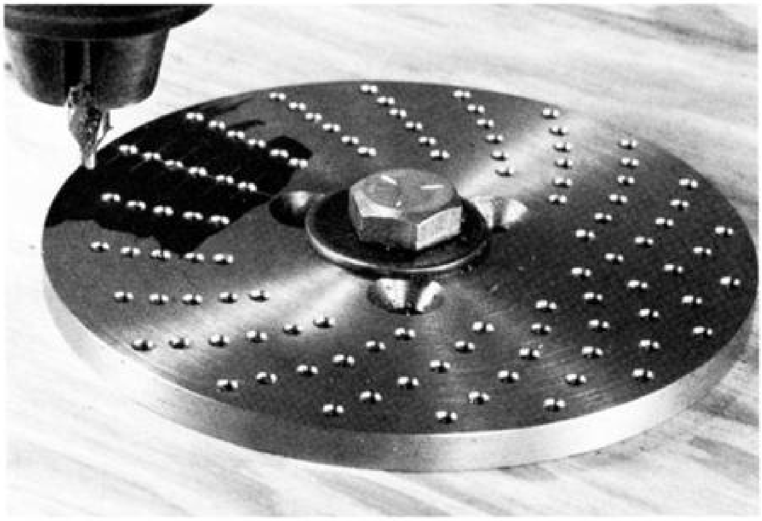
52

Since the plywood disk on our fixture is about 10" in diameter, it's necessary to cut at least five strips of 3/4" wide paper about 34" long. I cut my strips from a roll of adding machine paper. Cutting these strips the exact circumference of the wooden disk is simple. Wrap the first strip around the rim of the disk and overlap the ends an inch or two. Apply a short piece of adhesive tape over the outer end to keep the strip in place. Now, using a small square as a guide, make a vertical cut with a razor blade completely through the overlapped section of the paper strip – presto! One swipe and you have a strip the correct length! Cut the remaining strips to exactly that length.

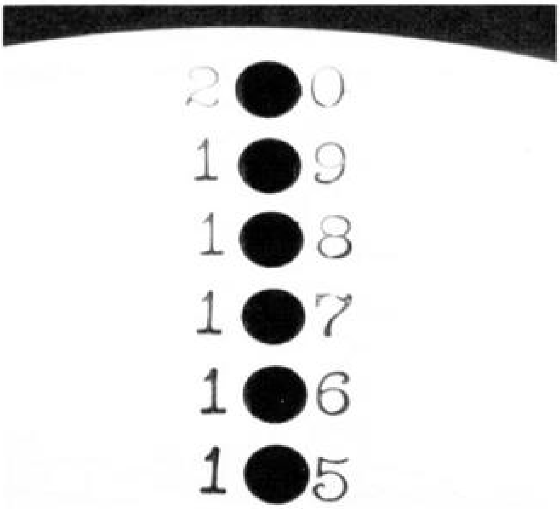
To lay out the divisions on these paper strips accurately, a drawing board of at least 2 x 3 feet is needed. Or a table with a truly straight edge along one side could be used. Finally, of course, you'll need an accurate T-square.

Remember, when drawing the division lines on the paper strips, use a fine-pointed pencil, not a ball point pen. The most accurate method would be to use a fine-pointed metal scriber and scratch the lines onto the strips. After scribing the first set of divisions on one of the strips, take a hand rule and carefully measure the distance between each line. They should all be equal. Now write the number of divisions on that particular portion of the strip. Also remember, if a strip calls for 20 divisions, you should have 20 spaces between one end and the other. The point where the ends of the paper strip touch is a division line.

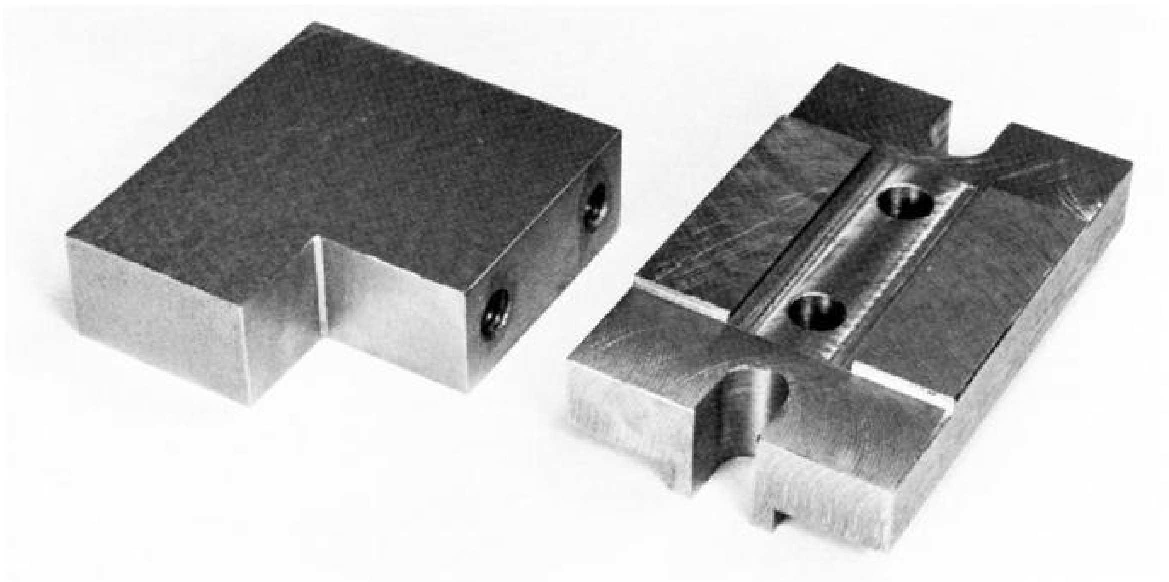
Referring to Photo C, position a blank index plate over the central bushing and bolt



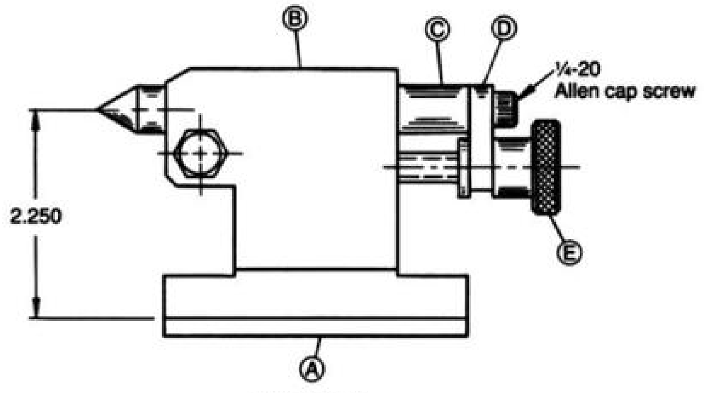
54



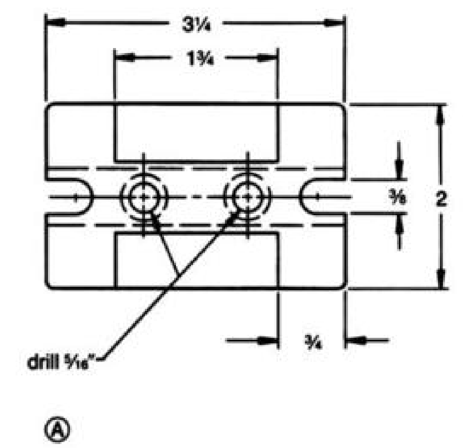
55

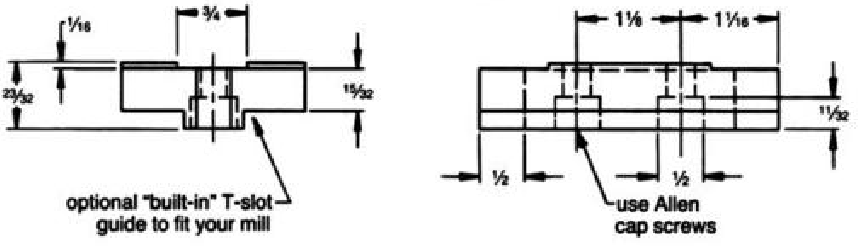


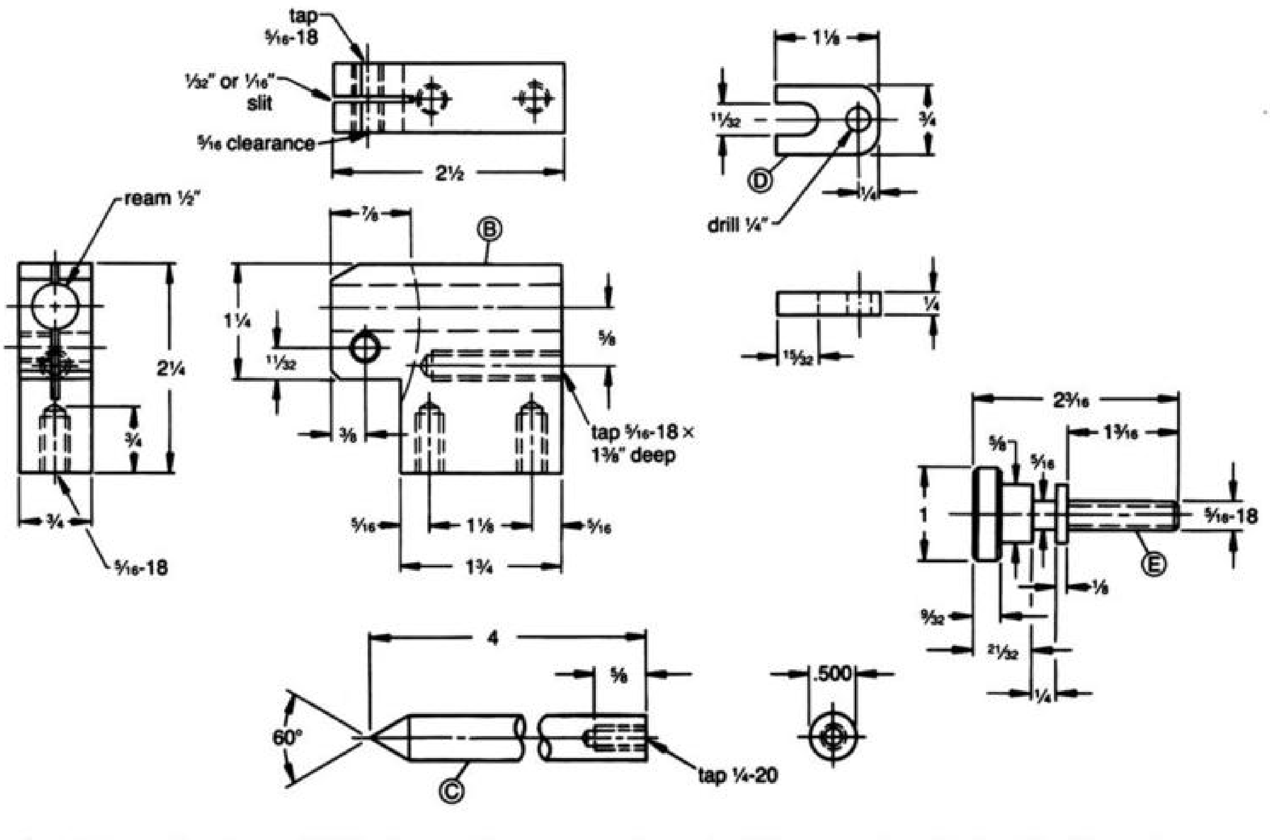
56


B
C
D
¼-20
Allen cap screw
2.250
E
A

TAILSTOCK


3¼
1¾
⅜
2
drill 5/16"
¾
A


1/16
¾
23/32
15/32
optional "built-in" T-slot
guide to fit your mill
1⅛
1 1/16
11/32
½
½
use Allen
cap screws

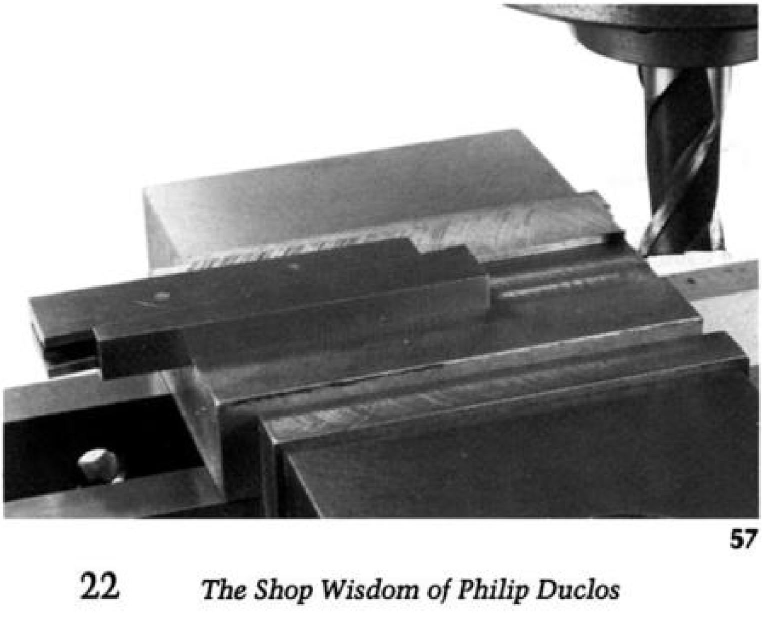

tap
5/16-18
1/32" or 1/16"
slit
5/16 clearance
2½
1⅛
11/32
¾
D
¼
drill ¼"
¼
15/32
ream ½"
2¼
¾
¾
5/16-18
⅞
B
1¼
11/32
⅝
⅜
tap 5/16-18 ×
1⅜" deep
5/16
1⅛
5/16
1¾
2 3/16
1 3/16
⅝
5/16
1
5/16-18
E
⅛
9/32
21/32
¼
4
⅝
.500
60°
C
tap ¼-20

it tightly to the plywood disk. Secure the paper divider strip around the plywood disk with adhesive tape. Loosen the drill press column clamp and swing the table to locate the No. 2 center drill (or smaller) over the first center line nearest the center of the index plate. This location will have the least number of divisions, the next will have more, etc. The drill press table must be shifted slightly for each different series of holes. You'll need some sort of supporting collar or C-clamp on the column beneath the drill press table column clamp. This is essential to maintaining the vertical position of the table every time the table locking clamp is loosened.

Now set the spindle depth stop so the 60° angle of the center drill forms a slight chamfer in the work not more than 1/32" wide across its face. Set the pointer over a line on the strip, clamp a C-clamp (Photo C) over the plywood disk and begin drilling. After a hole is drilled, loosen the C-clamp and revolve the plywood disk to the next division mark and again lock the C-clamp. When that circle of holes is complete, loosen the column clamp and swing the table in line with the next center mark. Lock the column clamp. Remove the paper tape from the plywood disk and install a new set of divisions. Again align the pointer with one of the division lines; lock the plywood disk and continue drilling. Repeat until all three index plates are completed. In Photo 54 an index plate nears completion.

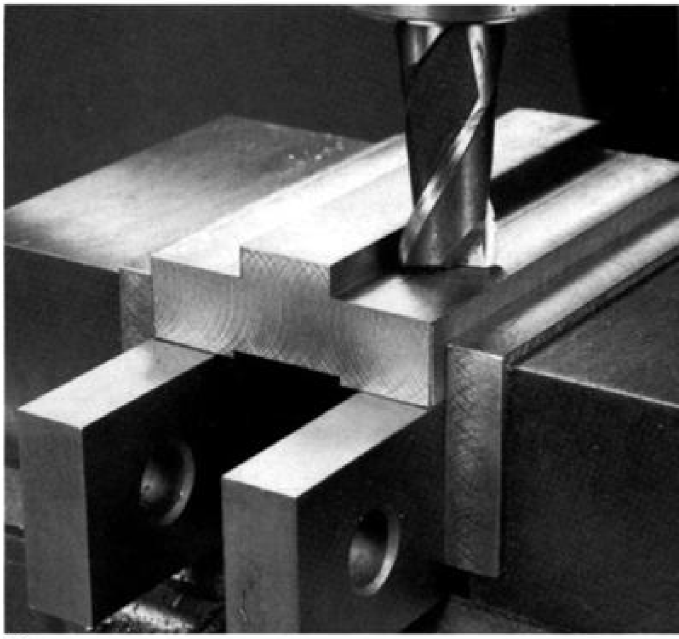
If you have a 1/16" set of number stamping dies, it's advisable to stamp the proper numbers adjacent to each set of holes (Photo 55), or scribe them with an electric pencil. The few remaining parts necessary for completion of the divider head are of simple design and need no comment.

Prior to commencing work on the tailstock unit, a brief explanation of simple indexing with the divider head would be appropriate. Bear in mind that the indexing crank on the divider has a ratio of 40 to 1. Let's assume that we wanted to cut 20 teeth on a gear blank; $\frac{40}{20} = 2$. Therefore, 2 would be the number of exact revolutions of the index crank. Any index hole in any of the three index plates could be employed, but the same index hole must be used for each of the 20 divisions. Suppose we wanted five divisions; $\frac{40}{5} = 8$ turns of the index crank. Again any index hole could be used to position the index crank.

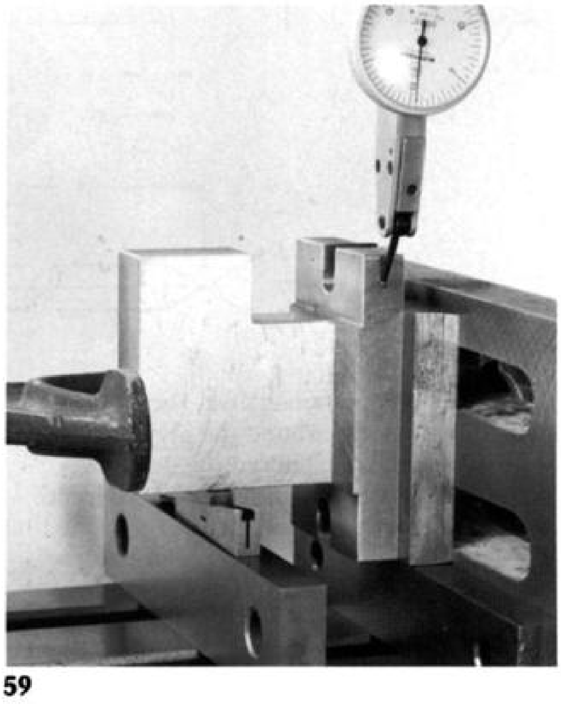


57

Now let's try 54 divisions, $\frac{40}{54}$. However, the largest series of holes on the index plates is 49. So the equation must be reduced; $\frac{40}{54} = \frac{20}{27}$ By using the 27 hole circle and by indexing 20 spaces between the holes, the correct division is obtained. The sector arms should be set to include one more hole than the number of spaces required. If one desired 360 divisions, $\frac{40}{360} = \frac{2}{18}$; you'd therefore use the 18 hole circle and set the sector arms for two spaces, or three holes. After indexing, always swing the sector arm so it will be in position for the next indexing operation. Any reputable machinist's



58



59

handbook will contain charts listing a large number of divisions and the appropriate indexing of the divider plates.

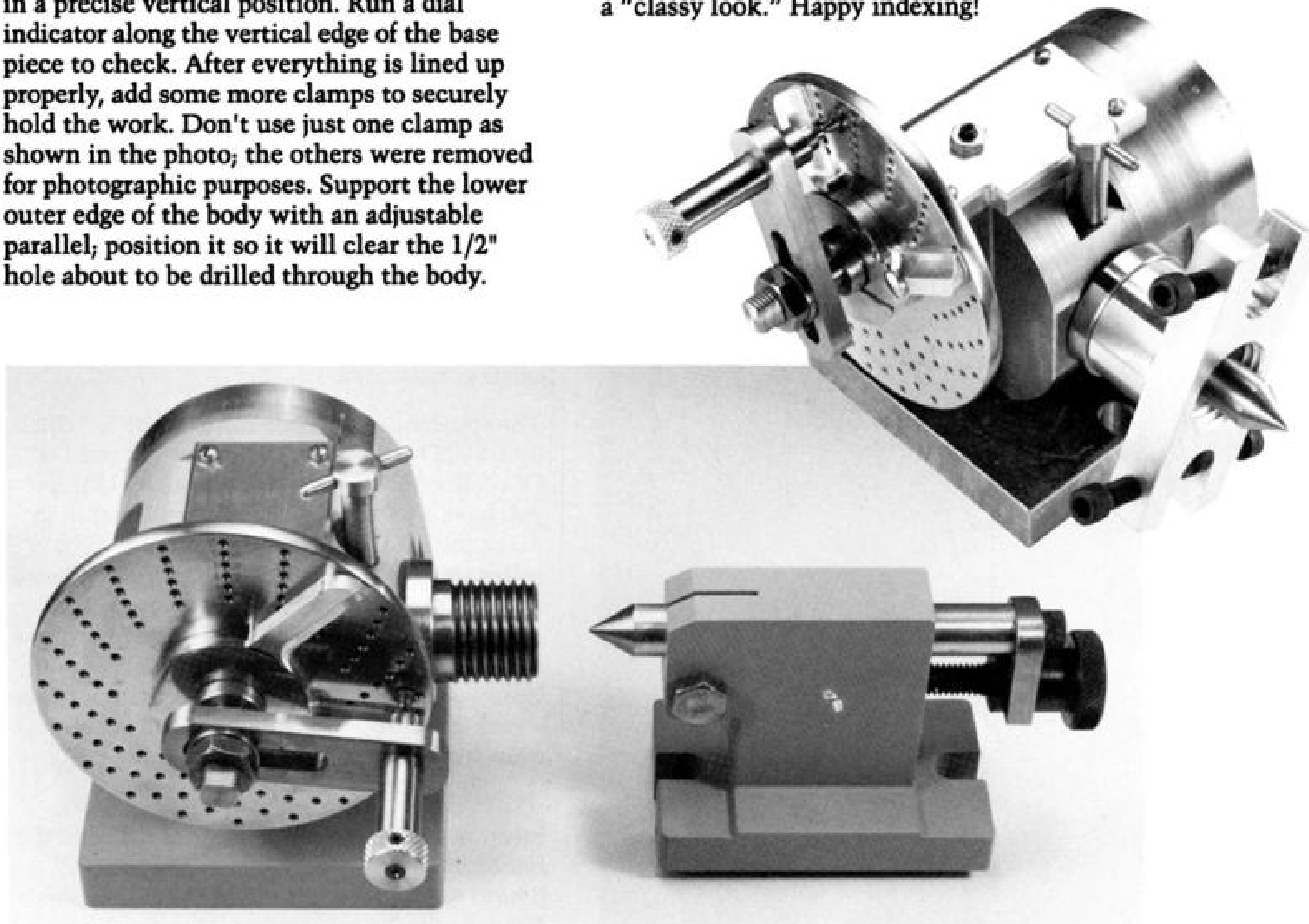
The tailstock body consists of two main pieces (Photo 56). I constructed mine from hot rolled steel; almost any type of metal could be used, including aluminum.

Begin by squaring up the base section. All surfaces should be square and parallel. Mill a 1/16" deep slot lengthwise in the exact center of the top surface of the base (Photo 57). This slot should be a snug fit for the vertical portion of the tailstock. You can either fit the vertical piece to the slot or fit the slot to the vertical piece. The width of the slot is easily measured with the aid of an adjustable parallel and a mike. I milled a tongue on the bottom of the base piece to match the T-slots in my mill (Photo 58); it should be in the exact center of the base.

After bolting the base to the vertical section, position it as shown in Photo 59. The supporting angle plate must be set parallel to the travel of the table; use a dial indicator. As we are about to drill and ream the 1/2" spindle hole, it's important that the sides of the base section are in a precise vertical position. Run a dial indicator along the vertical edge of the base piece to check. After everything is lined up properly, add some more clamps to securely hold the work. Don't use just one clamp as shown in the photo; the others were removed for photographic purposes. Support the lower outer edge of the body with an adjustable parallel; position it so it will clear the 1/2" hole about to be drilled through the body.

Now locate an edge finder against the bottom surface of the tailstock. Set the appropriate calibrated dial on the mill to zero. Then move the edge finder over to contact the side of the base section. Set the second calibrated dial to zero. Now mike the width of the base, divide by 2 and add half the diameter of the edge finder. The total is the amount necessary to position the mill spindle directly over the center line of the tailstock. Then lock the table in that direction. Now reposition the table in the other direction until the previously set calibrated dial reaches zero. The tailstock spindle center line is 2.250" up from the base surface. Move the table that amount, plus half the diameter of the edge finder, and lock the table. Carefully center drill, then follow through with a 1⁄4" drill. Gradually increase the drill sizes and finally ream the hole. While you have this set up, also drill and tap the hole for the tailstock spindle adjusting screw. The remaining parts are easily constructed, hence comment is not necessary.

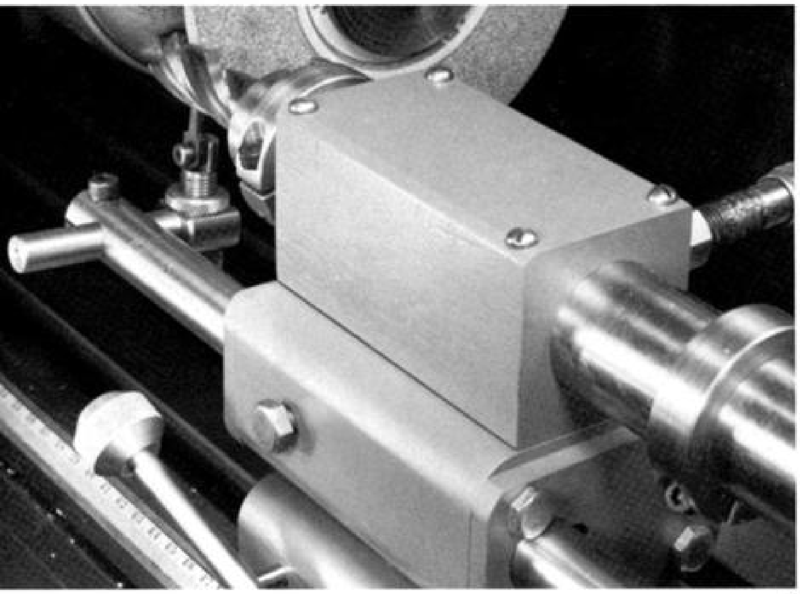
Be sure to grease all moving parts of the divider on final assembly. I painted certain portions of my divider and tailstock to give it a "classy look." Happy indexing!



"Floating" End Mill Sharpener

Do you have a drawer full of dull, beat up end mills? Well, I did have, so I decided to do something about it – and without spending a fortune in the process! Now I have a delicious assortment of sparklingly sharp end mills, rarin' to go to work!

There are at least two types of fixtures that will not only sharpen the tip of an end mill but also the cutting edge along the spiral flutes. They are usually used in conjunction with a tool and cutter grinding machine – an expensive combination! The most common of these fixtures has a hardened and ground spindle or quill, that holds the offending end mill. This type of spindle is supported at each end of the fixture body by three carbide, ball-tipped, adjustable rods, reminiscent of two miniature lathe center rests. Their function is to minimize friction on the spindle as the operator slides and turns it, allowing the finger support to follow the spiral grooves in the end mill. I believe that this type of fixture leaves a lot to be desired. There is a tendency for the guide finger, which is usually made from a flat strip of spring steel, to bind, skip, and jump as it traverses the spiral flute, all due to an excessive amount of friction between the spindle and its support. Therefore, I decided to build the second type of fixture. It employs compressed air to actually *float* the spindle on a blanket of air (Photos 1 and 2)! There is *no* metal-to-metal contact between the spindle and its housing! When testing my spindle with compressed air, I gave it a fast twirl with my fingers; it revolved for over three minutes despite the fact that it weighs about three pounds!



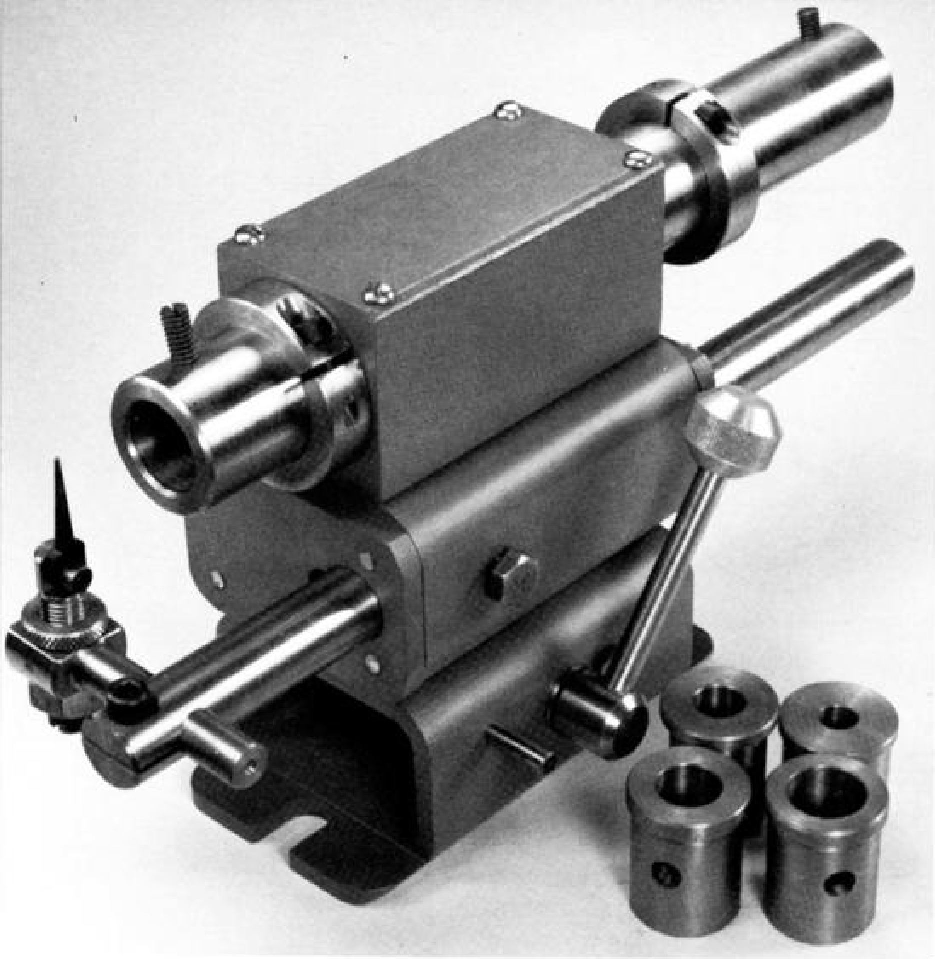
1

For this very unconventional method of sharpening end mills you'll need a vertical milling machine with a cross travel of at least 6"; you'll also need a bench grinder or other motor to be attached upside down to the milling machine spindle. Finally, of course, you'll need a source of compressed air. My little ½ hp single-cylinder, piston-type air compressor has a 2" bore and a 1¾" stroke; when chugging along at 575 rpm, it puts out just enough volume and air pressure to suffice perfectly. Another advantage of the air float-type spindle is that it doesn't have to be hardened. Air pressure escaping at both ends of its housing blows away any grit that might land on it and cause abrasion.

The Spindle and its Housing are the most difficult parts to make, so it's advisable to work on them first. The rest of the project is easily constructed.

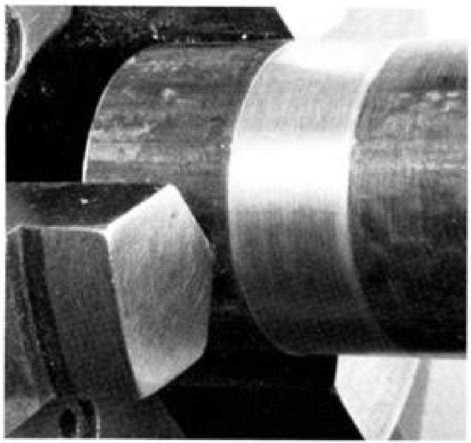
The spindle can be made from either 3/16" thick by 1⅜" OD steel tubing or from solid rod 1⅜" OD cold or hot rolled steel (Photo 3). Unless you have a tool post grinder, it's advisable to make the spindle from a solid piece of cold rolled steel; it's not necessary to drill a hole all the way through the shaft. I also tested a spindle machined from a welded seam piece of tubing. The quality of the steel was very poor, being sprinkled with tiny specks of impurities – very difficult to machine true and accurate, even with a carbide tool bit; however, it can be done.

Insert the piece of tubing, or solid rod, into the lathe chuck jaws for a distance of about ¾" (Photo 4). Do not overtighten the chuck jaws. Now machine a band about ⅝" wide. Remove



2

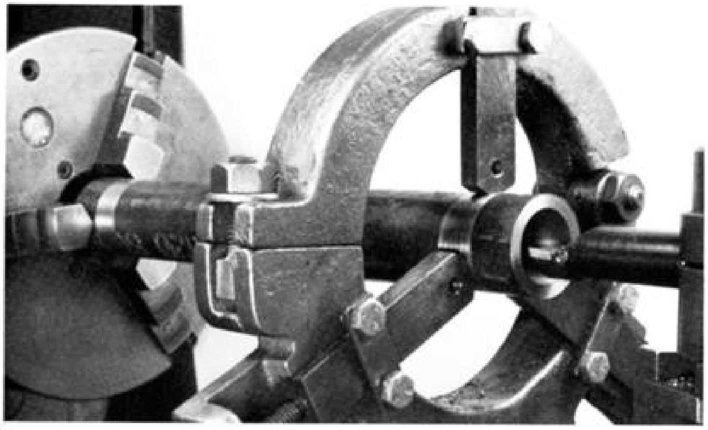
3



4

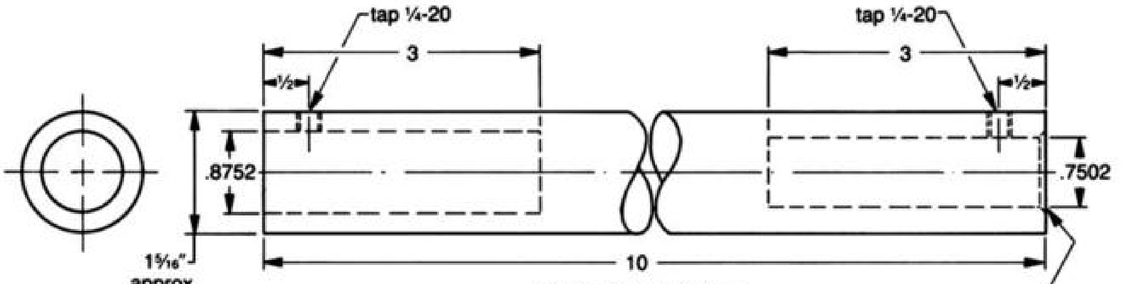
just enough metal to make this section smooth and *round*. Then reverse the piece in the chuck and prepare to do the same operation on the opposite end, but first try to make the outer end of the shaft run fairly true where it has been machined. Use a dial indicator. Since the chuck jaws have not been tightened too much on the workpiece, it's possible to gently push or pull on the outer end of the work until it runs fairly true. Now machine the second band close to the chuck; make it *exactly* the same diameter as the first one. Again check the band at the outer end for concentricity. Then move the lathe carriage to the right out of the way.

Without disturbing the work, carefully position the steady rest so its jaws are located in line with the outer machined band, as in Photo 5. Gently position each support bar to lightly touch the workpiece and lock them. Apply grease to this area. Tighten the chuck jaws just enough to prevent the work from shifting under the strain of drilling or boring. Face off the end of the tube or shaft. If you are using tubing, then bore it out to a depth of about 1½". In order to keep the wall of the tube as thick as possible, the diameter of this bore should be just large enough to make it run perfectly true. Be sure to check for taper in the

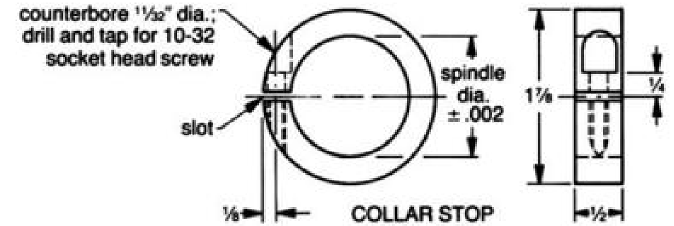


5

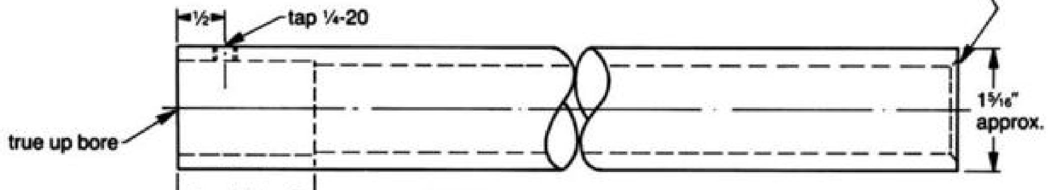
6


tap ¼-20
3
½
tap ¼-20
3
½
.8752
.7502
1 5/16"
approx.
10

SOLID ROD SPINDLE

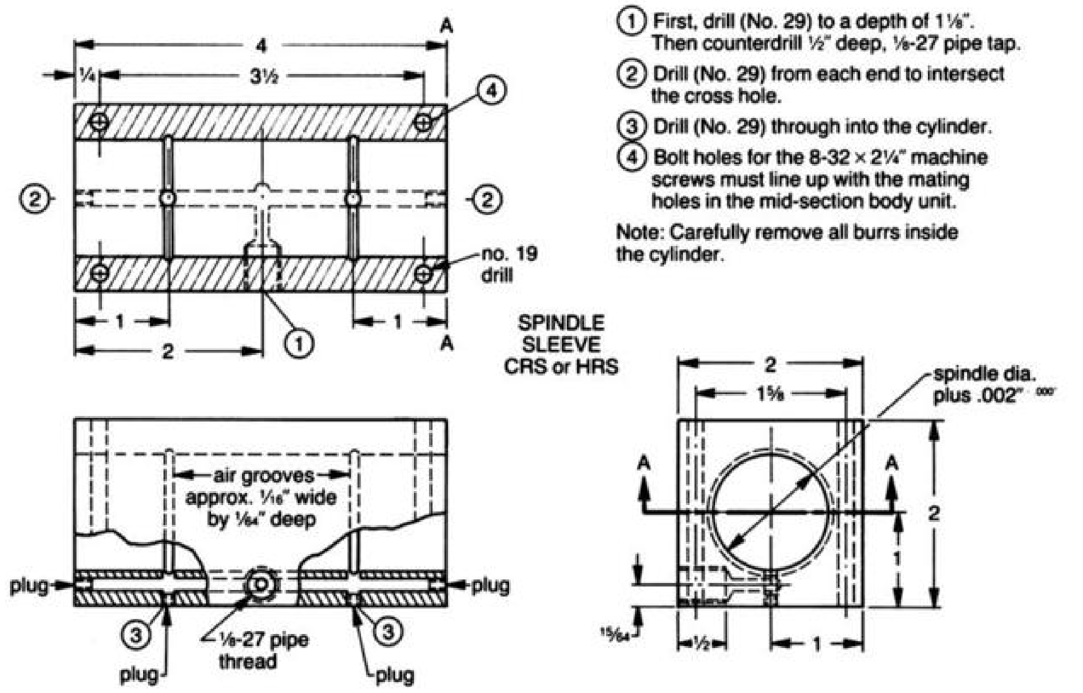

counterbore 11/32" dia.;
drill and tap for 10-32
socket head screw
slot
spindle
dia.
±.002
1⅞
¼
⅛
½

COLLAR STOP
CRS or HRS
2 required


½
tap ¼-20
true up bore
1½
1 5/16"
approx.

OPTIONAL TUBE TYPE SPINDLE

60° inclusive angle for the bull nose tailstock support when machining the OD of the spindle.


A
4
¼
3½
④
②
②
no. 19
drill
1
1
A
2
①
air grooves
approx. 1/16" wide
by 1/64" deep
plug
plug
③
③
plug
⅛-27 pipe
thread
plug
2
1⅝
spindle dia.
plus .002" .000"
A
A
2
1
15/64
½
1

① First, drill (No. 29) to a depth of 1⅛". Then counterdrill ½" deep, ⅛-27 pipe tap.

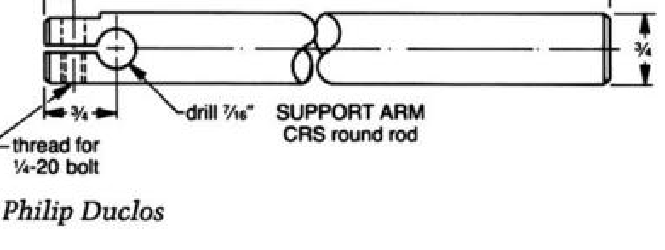
② Drill (No. 29) from each end to intersect the cross hole.

③ Drill (No. 29) through into the cylinder.

④ Bolt holes for the 8-32 × 2¼" machine screws must line up with the mating holes in the mid-section body unit.

Note: Carefully remove all burrs inside the cylinder.

SPINDLE
SLEEVE
CRS or HRS


11½
3/16
¾
¾
drill 7/16"
thread for
¼-20 bolt

SUPPORT ARM
CRS round rod

bore; if tapered, it's necessary to *slightly* shift the positions of the two lower support bars on the steady rest. If the bored diameter is larger at the outer end of the tube, slightly loosen the lower support bar nearest to you. Carefully adjust the rear lower bar to take up the slack; if tapered the other direction, reverse this procedure.

When employing a solid rod for the spindle there's an extra advantage. One end can be drilled and bored to hold a ⅞" end mill shank; the other end a ¾" shank – thus one less end mill bushing to make later on. However, it's necessary to drill and bore these holes to a depth of about 3" to provide room for the longer, double-ended mills. The solid spindle setup with the steady rest is identical to the tubing setup.

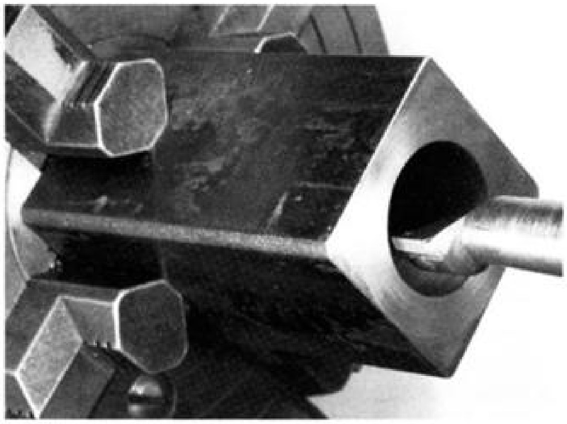
After facing off the solid end of the rod, center drill it. Now drill a hole 3" deep with a ¼" drill. Gradually increase the size of the drills until you approach ¾" or ¹³⁄₁₆". Mount a husky boring bar and take a couple of very light cuts to clean up the hole and make it run true. Check now for play between the spindle and the steady rest jaws. If too tight, the work will overheat, and if too loose, the bore will be inaccurate. Also check for taper in the hole and make adjustments on the steady rest. Now bore out to .8752". When removing the workpiece and the steady rest from the lathe, do *not* disturb the jaw settings on the steady rest. Unlock the upper portion of the steady rest, and swing it up and out of the way. Remove the work from the chuck. Now detach the steady rest and set it aside.

Chuck up a short piece of steel rod large enough in diameter to machine a snug fitting, self-locking stub arbor, about ¾" long (Photo 6). This must fit the bore that has just been machined in the spindle. Before slipping the bored end of the work onto the stub arbor, reinstall the steady rest on the lathe bed, but do not clamp it to the lathe yet. Position it approximately where it will contact the previously machined band near the outer end of the spindle. Swing the upper portion of the steady rest out of the way. Take the spindle and position the machined band on it in line with the two lower support bars of the steady rest; slide the steady rest *and* the spindle, as a unit, to the left until the bored end of the spindle slips over the stub arbor. Twist the workpiece clockwise until you feel the arbor lock. Now clamp the steady rest to the bed, swing the upper portion into position and lock it.

If your spindle is the solid type, again face off the end, center drill and then drill and bore out the hole to .7502" by 3" deep. Check for taper *before* reaching the finished size. Now set the compound at a 30° angle and machine a 60° taper about ¹⁄₁₆" wide in the end of the bore. This will be employed to support the end of the spindle with a bull nose, live tailstock center. If your spindle is the tube type, machine a 60° taper in it also. Loosen the support bars in the steady rest and remove the unit from the lathe. With the bull nose center in place, advance the tailstock to support the end of the spindle. It's now possible to machine the entire length of the work without hindrance. Lightly machine off enough metal so the OD is running true all over. Mike for taper near each end of the spindle. Amount of taper allowed – about *.0002"*!

The easiest and most accurate way to finish the spindle OD is with a tool post grinder; if not available, then use a carbide lathe tool bit. Hone a small radius on the corner of the cutting edge. The finished spindle diameter should be about 1⁵⁄₁₆" (not critical). As you approach this diameter, take very light cuts (.001") and use a fine carriage travel feed. Apply cutting oil to the work. Undoubtedly it will be necessary to adjust the tailstock several times to eliminate taper. On the final pass, advance the cross slide about .00025" and machine the entire length one direction and then back again without changing the cross slide setting. This applies whether you are using a grinder or tool bit. If there's a variation of more than .0002" in the diameter, adjust your lathe accordingly. Don't even think of using a flat file to smooth out any humps or hollows on the spindle. You can use a fine emery paper to smooth it slightly, but don't overdo it – it's quite easy to sand it out of round; that we don't want!

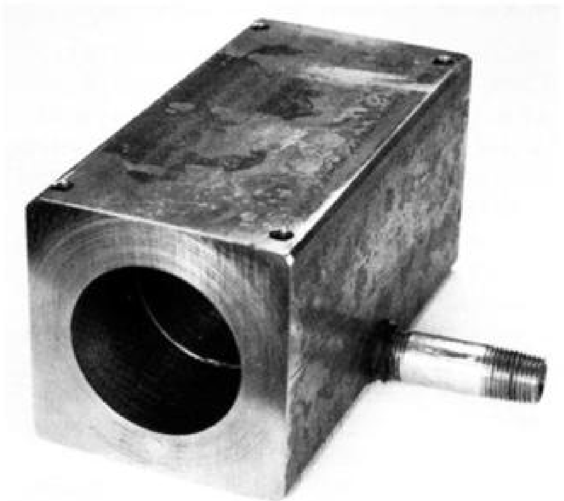
Machine the Spindle Housing (sleeve) next (Photo 7). Accurately center the block of (either hot or colled rolled) steel in a four-jaw chuck. Do not overtighten the chuck jaws – otherwise that end of the bored hole will be out of round when the work is released from the chuck. Drill and bore it out to .002" larger than the diameter of the spindle. At first glance this sounds rather easy. However, the bore in this sleeve should not vary in diameter more than *.0002"* from one end to the other. Use a sturdy boring bar, preferably carbide-tipped. If your lathe is old like mine, or if the lathe is not properly leveled, there'll undoubtedly be a tapered bore in excess of .0002". To overcome this problem I simply raise or lower one leg of



7

my lathe stand by adjusting the leveling screw on it. If the outer end of the bore is smaller than the other end, lower the front right leg of the stand; if it's larger, raise the same leg. Of course, start testing for taper *before* you arrive at the desired diameter. Usually this leg adjustment process will have to be repeated several times before eliminating the taper. If you are unable to get a straight bore even though the leg adjustments have left your lathe standing on three legs, it probably indicates that your lathe headstock spindle is not in line with the bed ways. That's another story!

After finishing the bore, mount a round-nosed tool bit (about 3/64" radius) in your boring bar. Proceed to cut the two circular air grooves in the cylinder; one of them is visible in the completed spindle housing in Photo 8. Remove the work from the lathe and carefully lay out the center lines for the air passages. In order for the spindle to float properly, it's imperative that the air holes enter into the cylinder cavity at its lowest point and in line with the two circular air grooves. Thus, when the spindle is in place and air pressure is applied, there's more pressure exerted beneath the spindle to overcome its weight and render it airborne. You can plug the unwanted sections of the air passages on the bottom and ends of the sleeve by merely threading them with an 8-32 tap to a depth of ⅛". Apply a little *Loctite* or gasket cement to the hole and firmly screw in an 8-32 machine screw. Cut off the surplus portion of the screw, then file flush with the body.



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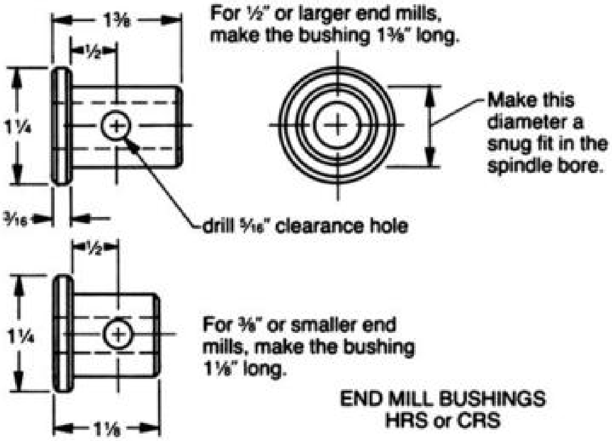
After completing the sleeve block, test it by inserting the spindle and hooking up the air pressure. Your compressor should have a combination pressure regulator and gauge to control the amount of air entering the fixture. Also *never* operate a compressor without an automatic safety pressure release valve on the tank.

The solid type spindle appears to float best at pressures from 40 to 90 psi. The tube-type spindle takes about 30 to 40 psi.

Let's assume we've goofed and accidently bored out the sleeve to .0035" larger than the spindle. When air is applied to the unit, the pressure will lift up the spindle to float; but as it rises, more of the air pressure will escape beneath the spindle due to the larger space. This causes the spindle to elevate higher yet in the sleeve and metal-to-metal contact is the result. However, the shaft can be made to float by reducing the air pressure to perhaps 20 psi. A sloppy fit is not advised. A space of less than .002" between the spindle and sleeve diameters will result in only a partial floating action, regardless of the amount of air pressure.


1⅜
For ½" or larger end mills, make the bushing 1⅜" long.
½
1¼
Make this diameter a snug fit in the spindle bore.
3/16
drill 5/16" clearance hole
½
1¼
For ⅜" or smaller end mills, make the bushing 1⅛" long.
1⅛

END MILL BUSHINGS
HRS or CRS

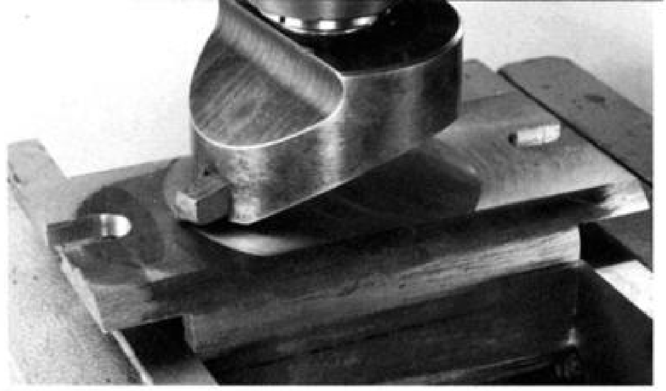
Now make as many End Mill Bushings as you'll need to fit the shanks of your end mills, ⅜", ½", ⅝", etc. The OD of the bushings should be a *snug* slip fit into the spindle hole. The bore of each bushing should be perfectly concentric with its OD, so bore it to size – don't ream it!

Let's start work on the Base section of the fixture. It's fabricated from ¼" thick hot rolled 2 × 3" rectangular tubing – available at most steel supply centers. Step cut each end of the tubing, then mill the hold-down bolt slots. Finally, fly cut the base surface just enough to clean it up (Photo 9).

As illustrated in Photo 10, the Camshaft housing is held in place in the fixture base by means of two screws; this is accomplished by first inserting the blank block in position inside the body and, with the aid of an adjustable parallel, wedge the block up against the ceiling. Now fasten a C-clamp against the vertical side of the block and the outside of the housing. Drill, tap and counterbore down through the housing and into the block for two 10-32 × ½" socket head cap screws. After the block is permanently bolted in place, drill and ream the ⅜" hole through the side of the body and the block. Follow by drilling and reaming the ¼" hole down from the top until it intersects the ⅜" hole. Ream out any resulting burrs.

All base section parts are shown in Photo 11. Note the two center drill indentations located near each end on the top surface. These will position two ball bearings (that act as a hinge) in line with two identical and equally spaced indentations to be made in the midsection portion of the fixture. I disassembled an old auto clutch thrust bearing to obtain the 5/16" balls; their size is not critical – ¼" or ⅜" balls could be employed.

When building the camshaft, I found it easier to drill the hole for the handle before milling the cam flat on the shaft. Referring to Photo 12, insert a short piece of rod (slip fit) into the handle hole. Position the work so the rod tilts at 25°. Now mill the flat for the cam. In the completed base section (Photo 13), note how the largest of the two flat washers is engaged in the groove on the handle hub. This allows the cam to rotate without slipping out of the body.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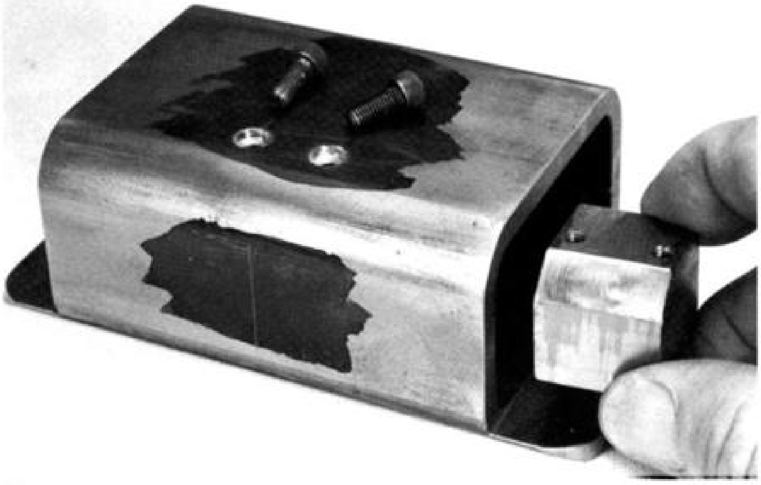
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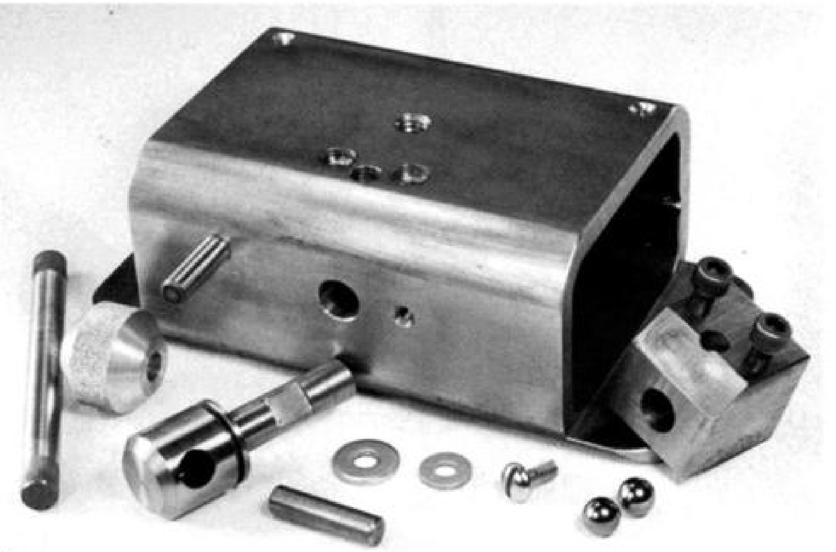
The mid-section portion of the fixture is very simple (Photo 14). The upper surface has a large clearance hole for inserting the bolt and *heavy* compression spring. There is also a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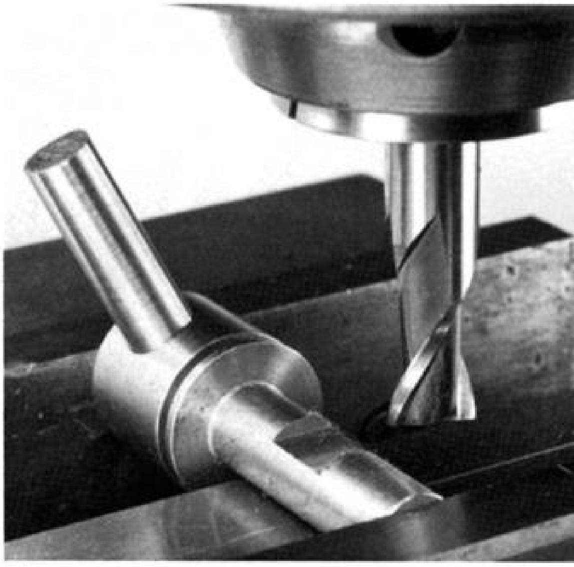
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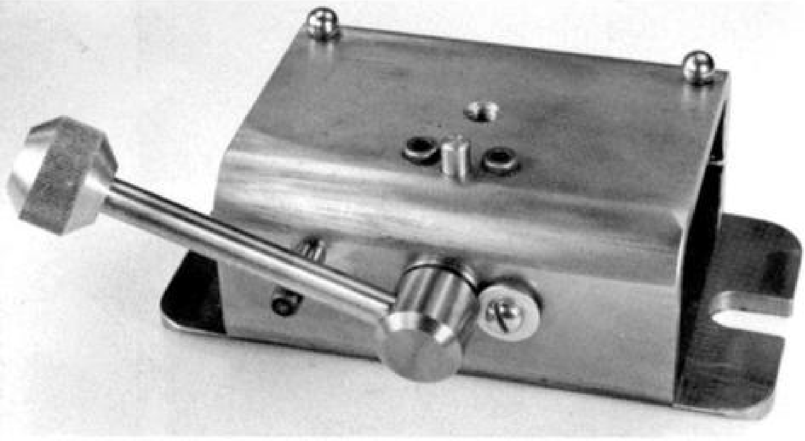

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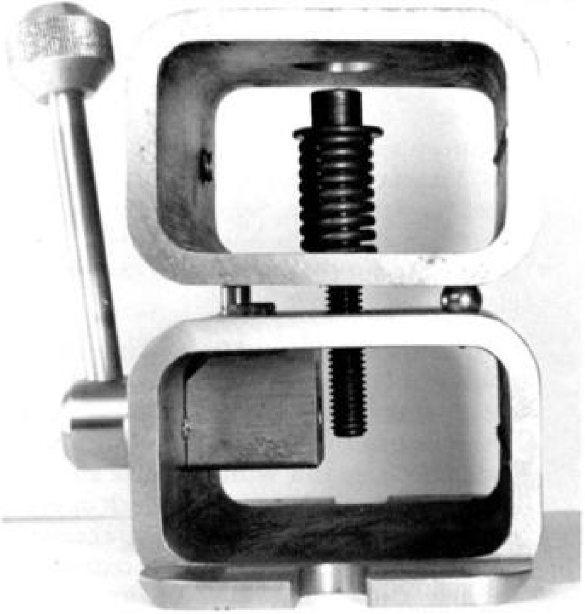

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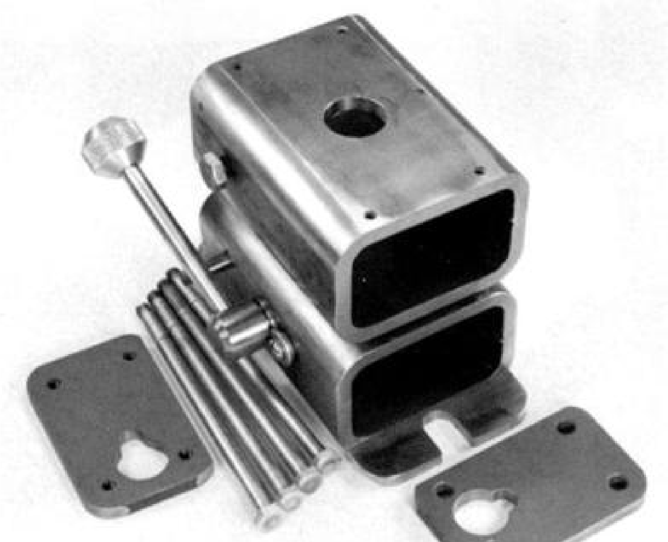
smaller clearance hole in the bottom for the bolt to pass through. This bolt is threaded into the *lower* unit. When the cam lever is activated, the push rod near the left will slightly raise or lower that side of the midsection body. This results in a tilting action, necessary when sharpening the cutting edge along the spiral flutes of an end mill. Photo 15 shows the two end plates and the four long ¼" bolts that secure them to the midsection housing.

The balance of parts necessary to complete the fixture need little explanation, except, perhaps, the vertical threaded rod that supports the Finger (Photo 16). In the lathe, chuck up a piece of 7/16" rod that is at least an inch longer than the finished product. Machine the 7/16-20 thread. If you possess one of those handy "spin-index" fixtures for your mill, mount the workpiece as in Photo 17 – if not, clamp the rod in your mill vise with the aid of a V-block and let the work extend horizontally from the side of the vise. Now mill the keyway slot. Revolve the work 180° and mill the flat (Photo 18). Also drill and tap a hole through the flat before removing the work from the mill. Finish by cutting off the surplus portion of the rod.

I adapted an old ¼ hp motor and attached it to the spindle of my vertical mill (Photo 19). In theory, it should be a 3450 rpm motor. Mine is a 1725 rpm motor, and it performs satisfactorily – mainly because very light grinding cuts are employed when sharpening end mills. Perfer-



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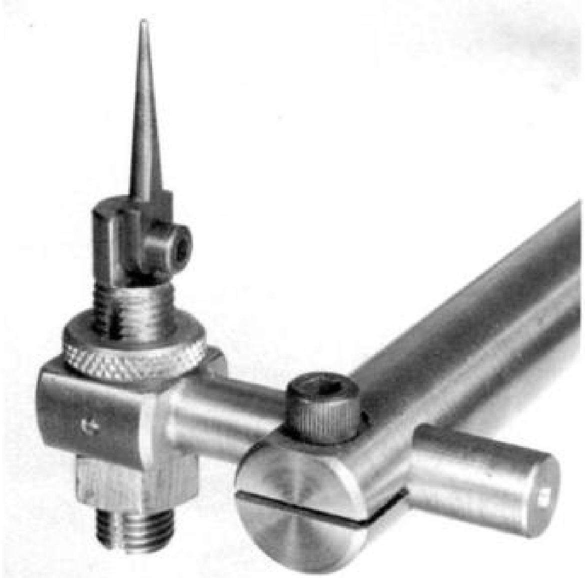

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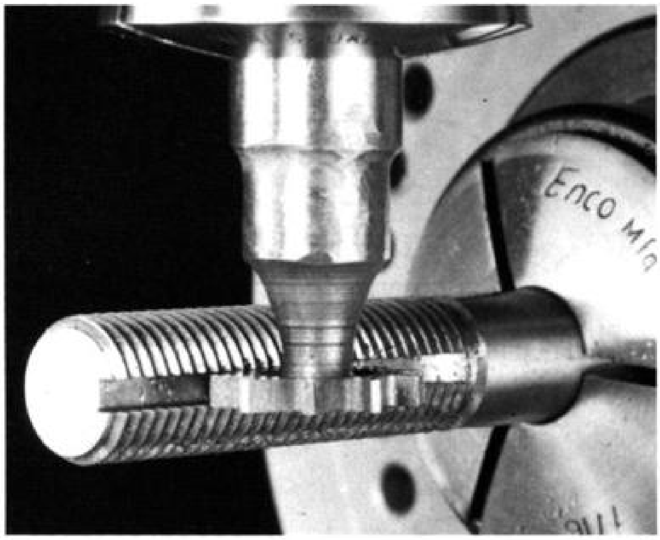

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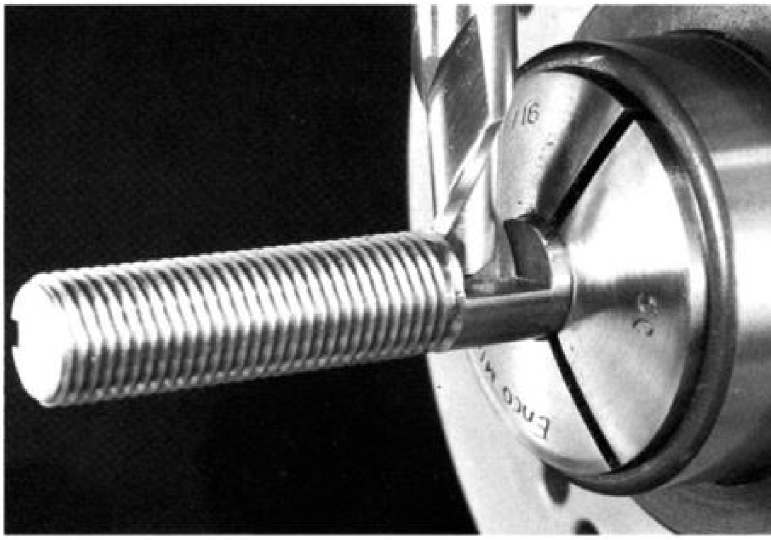

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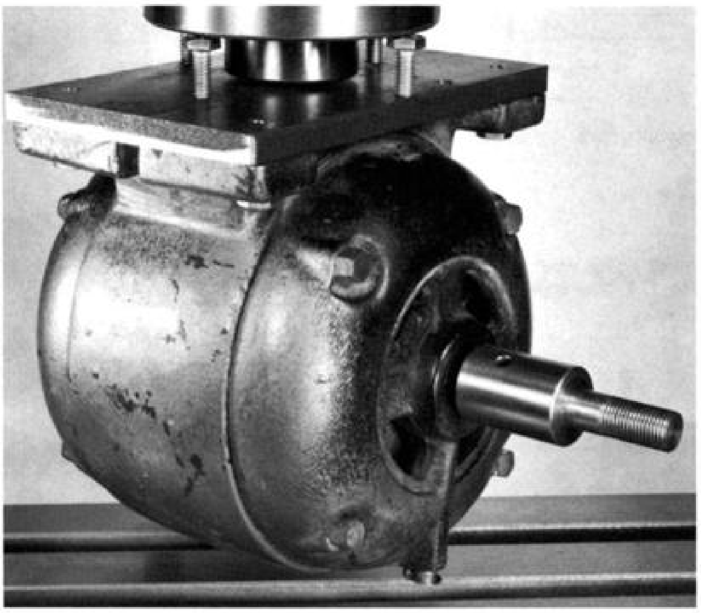
ably, your motor should be equipped with ball bearings. Since we are not using a cup grinding wheel in this unconventional setup, a sleeve bearing motor would be okay – if the bearings are in good condition. The Motor Base must be rigidly attached to the motor – no rubber mounts between motor and base!

The easily constructed motor adapter plate in Photo 20 must be altered to conform to your motor base. The ¾" shaft in the center of the plate was step-cut down on one end and threaded ½-20 for a distance of ⅜" (the thickness of the hot rolled plate). A hole in the center of the plate was tapped ½-20, some *Loctite* applied to the threads and the shaft tightened in place. When mounting to your mill, the ¾" shaft is inserted into a collet in the mill spindle (Photo 19). After locking the collet, the four ¼-20 bolts are lightly screwed upward with an end wrench to contact the outer end of the quill, and thus hold the motor in place.

I machined a grinding wheel adapter shaft to slip over the regular motor shaft; it should run as true as possible. The shaft as shown in Photo 19 should turn in a counterclockwise direction.

You'll also need to construct a simple Diamond Wheel-Dressing Fixture with which to true up the grinding wheel (Photo 21). I used hot rolled steel for the ¾" square (or larger) vertical piece and ¼ × 1" flat stock for the base section. Two ¼-20 bolts secure the pieces together. Drill the hole for the diamond dresser at a 15° angle.

When dressing the wheel, take very light cuts with the diamond – not over .001". I employed a wheel 6" in diameter by ¼" thick. If you can't obtain one that narrow, use a ½" thick wheel and step cut the OD slightly along one side of



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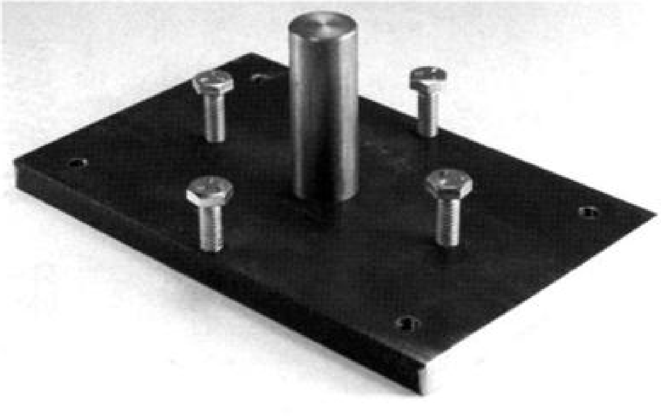

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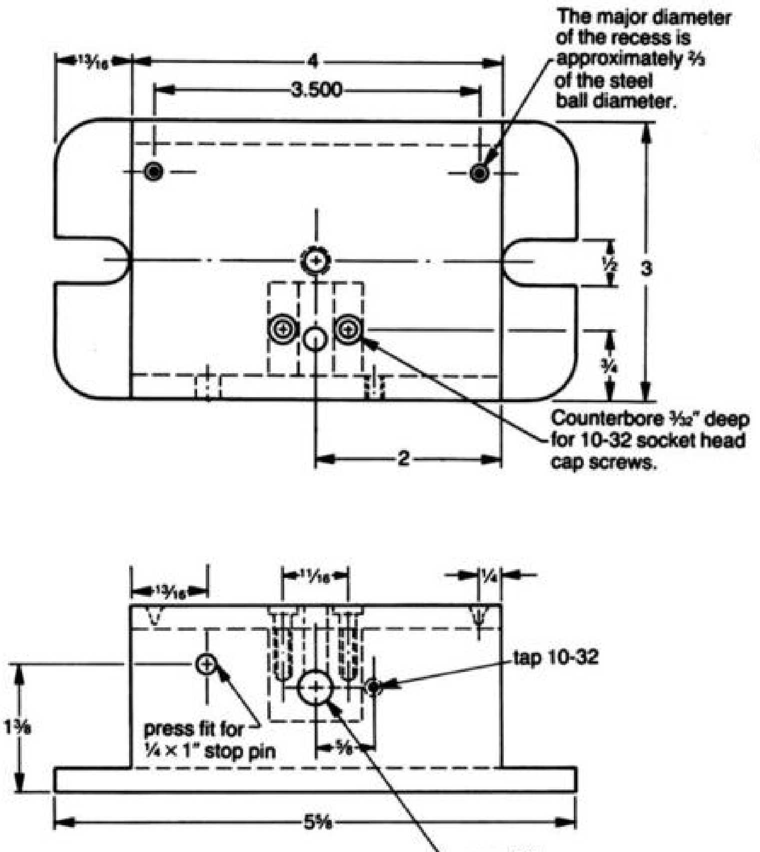
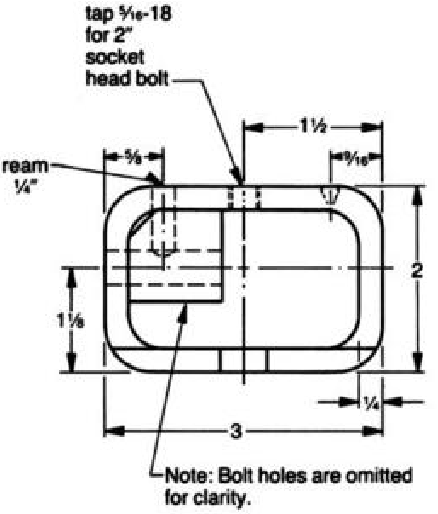
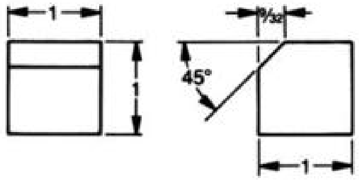


13⁄16
4
3.500
The major diameter of the recess is approximately ⅔ of the steel ball diameter.
½
3
¾
Counterbore 3⁄32" deep for 10-32 socket head cap screws.
2
13⁄16
11⁄16
¼
tap 10-32
1⅜
press fit for ¼ × 1" stop pin
⅝
5⅝
ream ⅜"

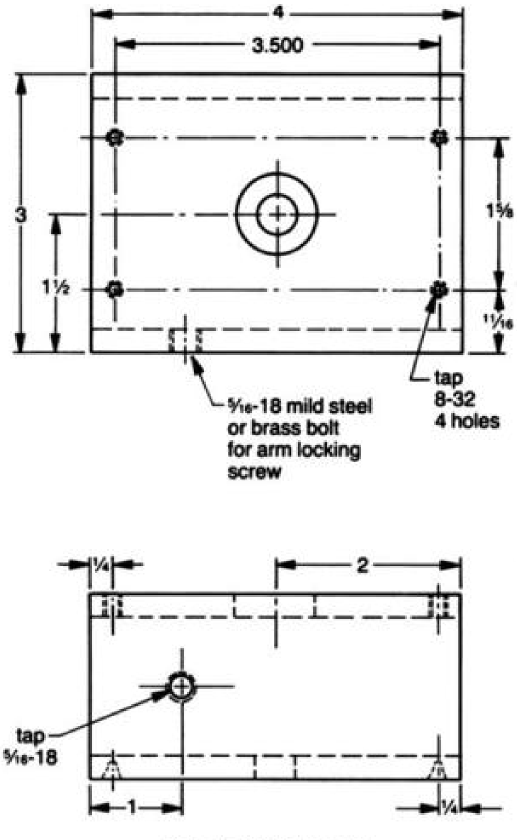
FIXTURE BASE UNIT



tap 5⁄16-18 for 2" socket head bolt
1½
ream ¼"
⅝
9⁄16
2
1⅛
¼
3
Note: Bolt holes are omitted for clarity.

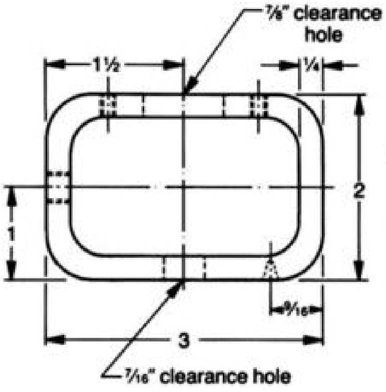


STEEL CAM SHAFT BEARING BLOCK BLANK
CRS or HRS

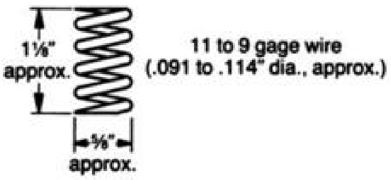


4
3.500
3
1⅝
1½
11⁄16
5⁄16-18 mild steel or brass bolt for arm locking screw
tap 8-32 4 holes
¼
2
tap 5⁄16-18
1
¼

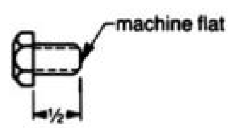
MID-SECTION BODY



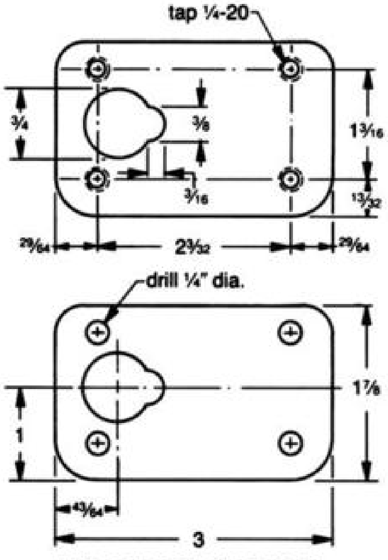
⅞" clearance hole
1½
¼
2
1
9⁄16
3
7⁄16" clearance hole



1⅛" approx.
11 to 9 gage wire (.091 to .114" dia., approx.)
⅝" approx.



machine flat
½



tap ¼-20
¾
⅜
13⁄16
3⁄16
13⁄32
29⁄64
2 3⁄32
29⁄64
drill ¼" dia.
1⅞
1
43⁄64
3

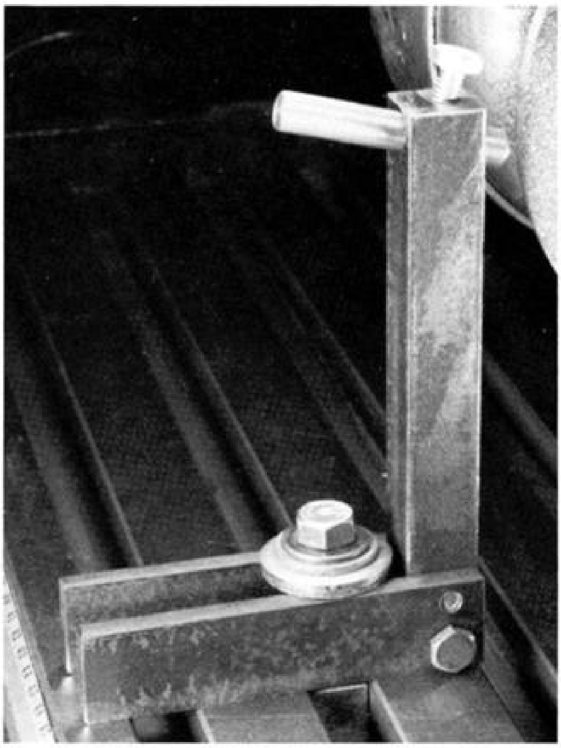
MID-SECTION END PLATES
2 required
¼" CRS or HRS

perimeter with the diamond dresser. Leave a band from 1/8" to 3/16" wide protruding about 1/64" above the rest of the diameter. Use a medium or fine grit wheel. It's also advisable to rig up some sort of wheel guard over the grinding wheel.

Let's sharpen an end mill! Mount the fixture near the right-hand end of your mill table (refer back to Photo 1). Position it fairly well in line with the T-slots (by eye-sight) and bolt it down. For practice, insert an old beat-up end mill in the spindle. Adjust the support finger (Photo 22), close to the outer rim of the flute and the tip of the end mill. The cutting edge of the end mill should be horizontal. Now locate the front collar on the spindle about 3/16" away from the front of the fixture body and lock it; thus the end mill can be pulled back and off the guide finger for indexing to the next flute. The primary clearance angle of the cutting edge along the flutes should be about 5°. So raise the center line of the grinding wheel higher than the center line of the spindle in the fixture, roughly 3/8". Double check the angle as in Photo 23. In this photo the grinding wheel has been swung around parallel to the mill table, preparatory to sharpening the end of an end mill later on. However, the principal is identical. Set the protractor angle at 5°. Let's assume that the center line of the fixture spindle is 5¼" above the mill table. Raise or lower the grinding wheel until its perimeter touches the edge of the protractor 5¼" up from the table. The cam action lever on the fixture should be in the down position against the stop pin. Examine Photo 24 closely. Note that the tip of the end mill barely clears the sides of wheel. Photo 25 is a rear view of the same setup.

The position of the end mill for the beginning of the grinding procedure is illustrated in Photo 26. The end mill has been advanced by gently pushing and turning the spindle slightly to induce the guide finger to follow the spiral groove; this motion is halted when the finger begins to bind in the shallower groove near the shank of the end mill. At this point, slide the rear stop collar along the spindle until it contacts the fixture body and lock it there.

Remember to cover any exposed ways on your mill table to protect them from grit. Connect the air hose to the fixture and put on your safety goggles. Grip the rear end of the spindle lightly with your fingers to hold the end mill in its starting position (Photo 26). Turn on the air pressure to the required amount. With your left hand, advance the mill cross slide until the grinding wheel barely touches the cutting edge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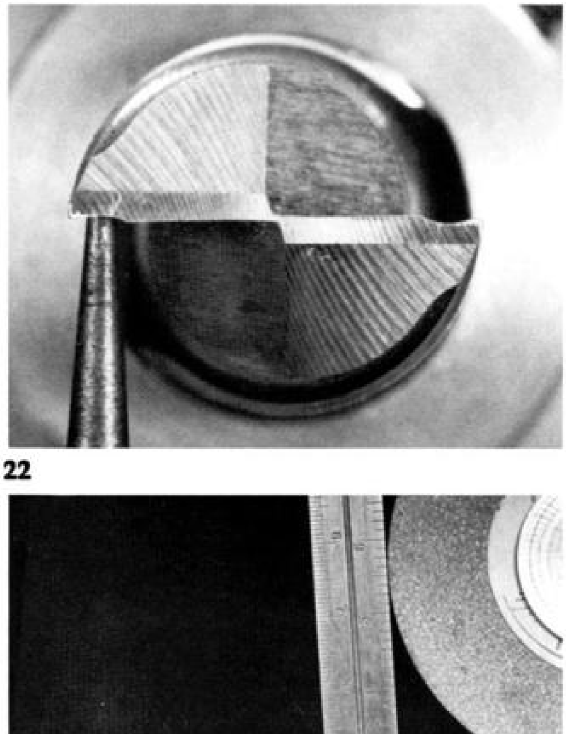
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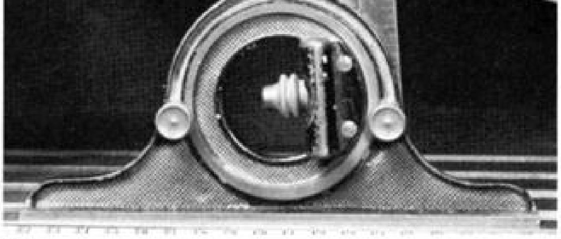
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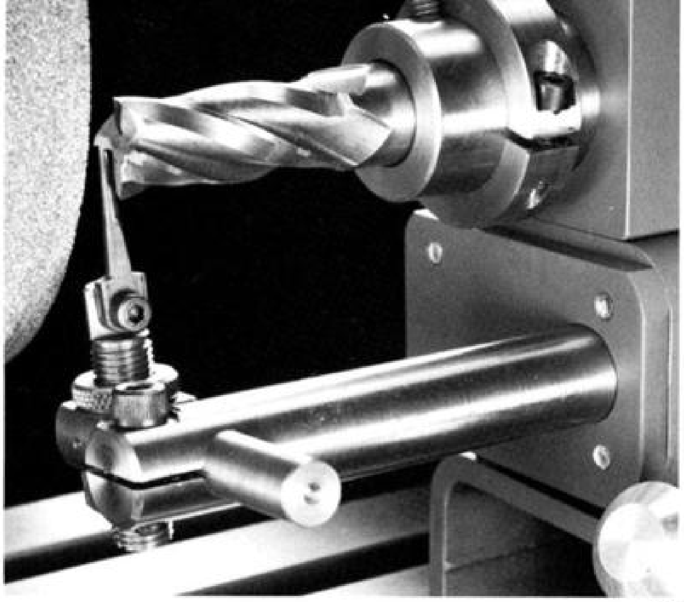

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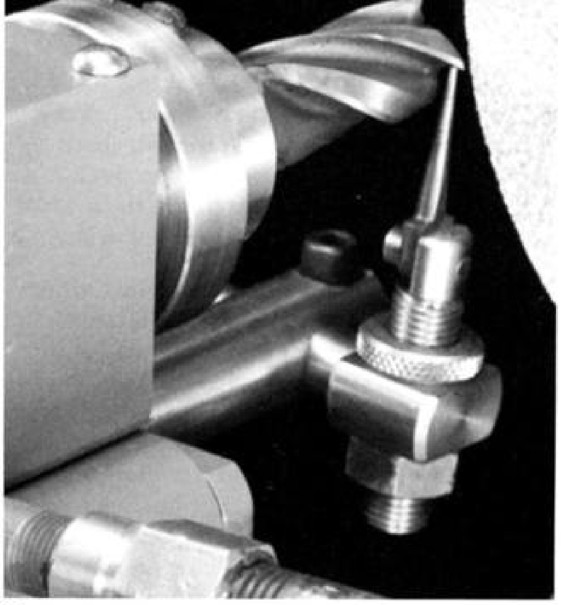

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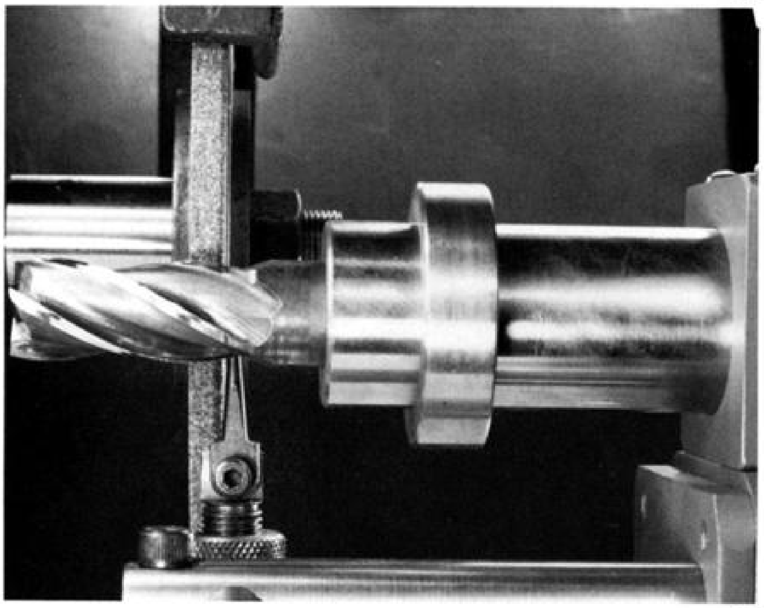

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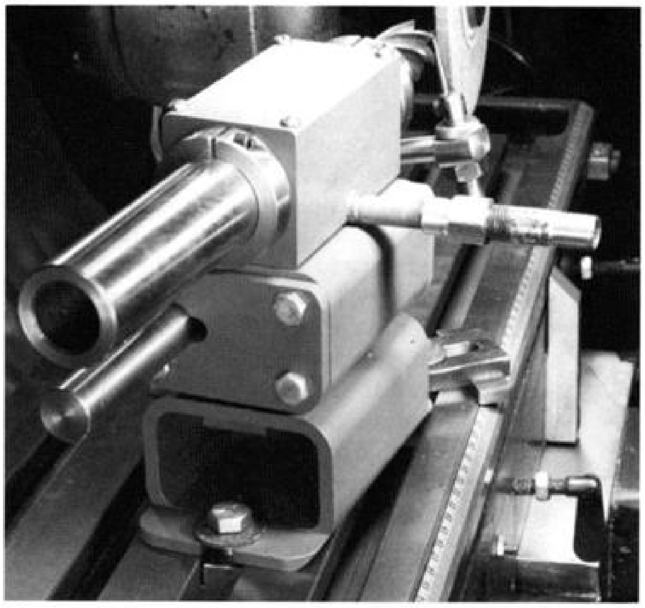

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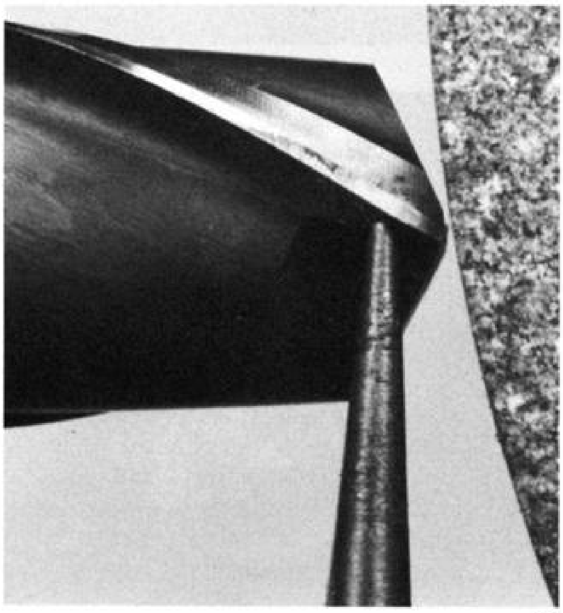

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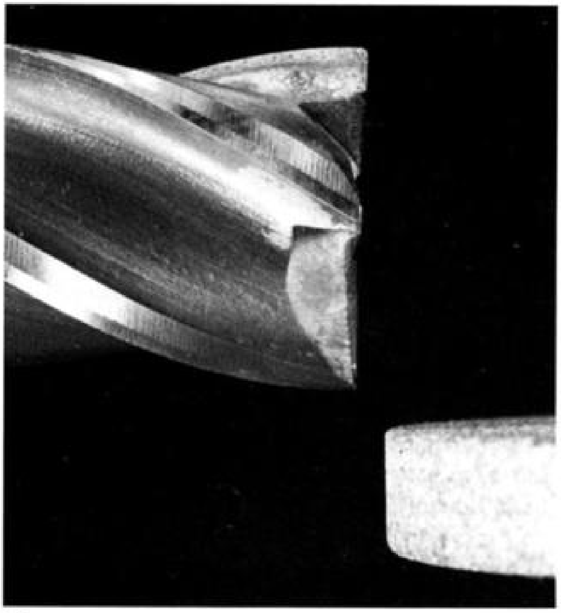

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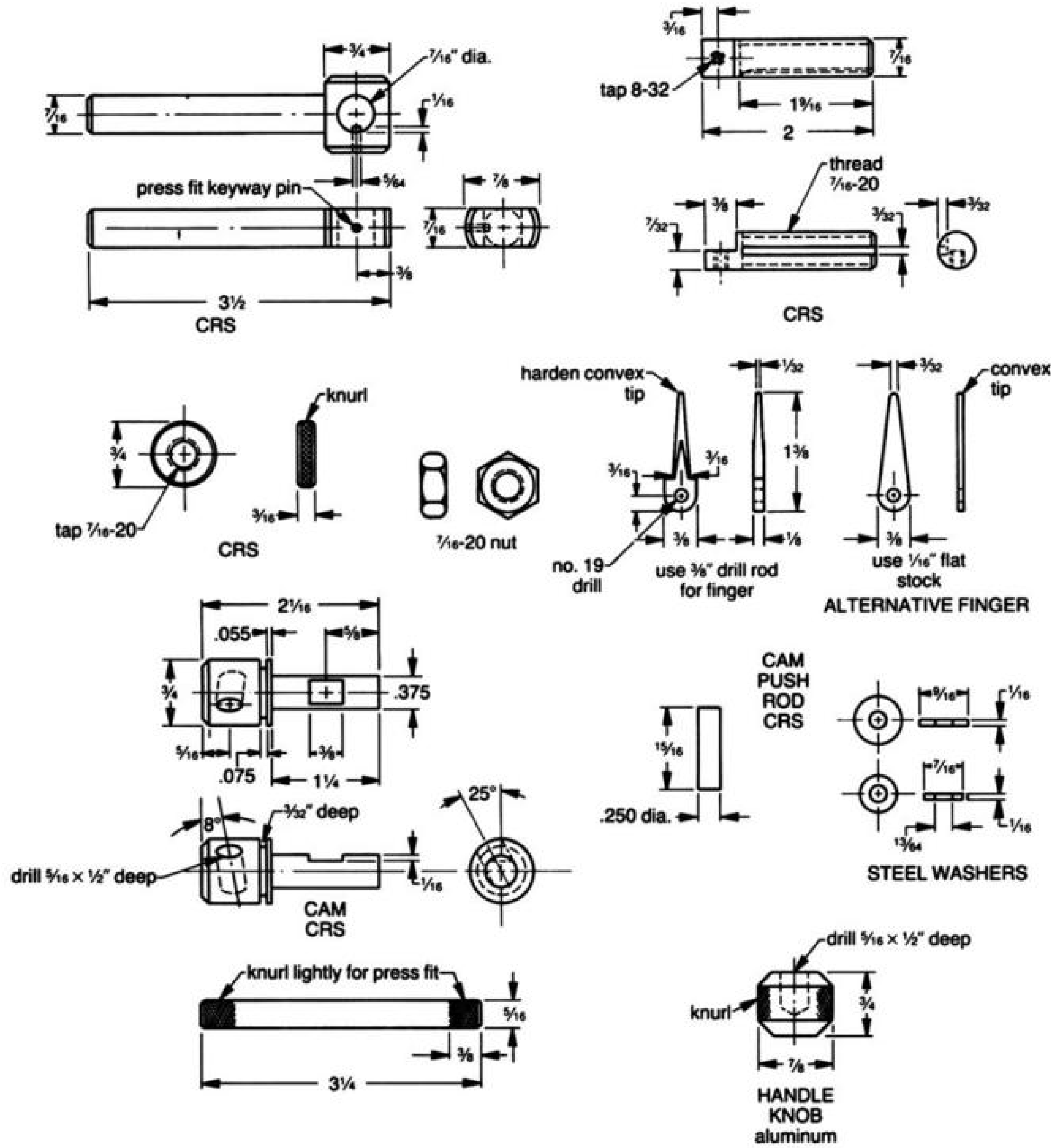
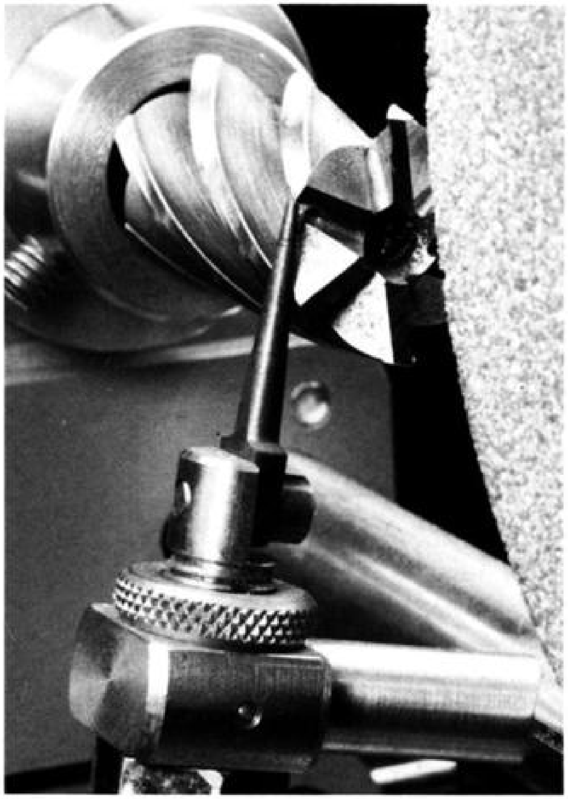

¾
7/16" dia.
7/16
1/16
press fit keyway pin
5/64
7/8
7/16
3/8
3½
CRS
3/16
tap 8-32
7/16
1 9/16
2
thread
7/16-20
3/8
7/32
3/32
3/32
CRS
knurl
¾
tap 7/16-20
3/16
CRS
7/16-20 nut
harden convex tip
1/32
3/32
convex tip
3/16
3/16
1 3/8
3/8
1/8
3/8
no. 19 drill
use 3/8" drill rod for finger
use 1/16" flat stock
ALTERNATIVE FINGER
2 1/16
.055
5/8
¾
.375
5/16
.075
3/8
1¼
25°
8°
3/32" deep
drill 5/16 × ½" deep
1/16
CAM CRS
CAM PUSH ROD CRS
15/16
.250 dia.
9/16
1/16
7/16
1/16
13/64
STEEL WASHERS
knurl lightly for press fit
5/16
3/8
3¼
drill 5/16 × ½" deep
knurl
¾
7/8
HANDLE KNOB aluminum

on the side of the end mill. Gently and slowly pull back on the spindle allowing it to turn as you keep the spiral flute in contact with the tip of the guide finger. Continue this action until the tip of the end mill has passed beyond the support finger.

Now elevate the cam lever arm to tilt the spindle and its end mill *away* from the grinding wheel. *Always* remember to do this; otherwise you may end up with a badly nicked end mill! Now turn the spindle until the next cutter flute is in line and position it on the support finger. Advance the end mill with a push and turn motion as far as it will go. Then lower the cam shaft lever to bring the grinding wheel in contact with the end mill. Again slowly pull and turn the spindle until the end mill has escaped from the support finger. Raise the cam lever. Continue repeating this process until all of the spiral cutting edges have been ground.

Carefully examine the cutting edges along each flute to verify their sharpness. If still dull, advance your milling machine cross slide another .001" and repeat the entire process until sharp. The same setup is employed for grinding the secondary clearance angle along the spiral. Merely set your protractor at a 15° angle. Raise the height of the grinding wheel until its perimeter contacts the protractor in line with the center line height of the fixture spindle. Grind this relief angle along the mill spiral to within approximately 1/32" of the cutting edge.



30

To save time, sharpen all of your dull end mills along the flutes first, since a different setup is used to sharpen an end mill tip. No air pressure is necessary with this process, so remove the air hose. Reposition the fixture at the opposite end of the mill table. Swing the grinder unit around 90° so the wheel is paralled (not critical) to the table. Resharpen the grinding wheel. Note that in Photo 27, the fixture is positioned at an excessive angle of 15° in relation to the table; this is necessary only for the six-flute end mills. This angle should be about 2° for the two-, three-, and four-flute cutters. Reposition the height of the grinder for a 5° angle (Photo 23). The support finger is again positioned (for two-, three- or four-flute mills) as in Photo 22.

A side view of the same setup is in Photo 28. The rear stop collar on the spindle is brought up to hold the end mill from advancing further. Now the front stop collar should be locked about 3/16" away from the spindle sleeve body; thus the end mill can be pulled back beyond the support finger for indexing. When sharpening, the wheel is brought in from the side of the end mill. The cross slide travel of the milling machine is utilized for this motion. Photo 29 is a view looking straight down; in this instance a four-flute end mill is in position. For clarity, the finger support mechanism underneath has been removed.

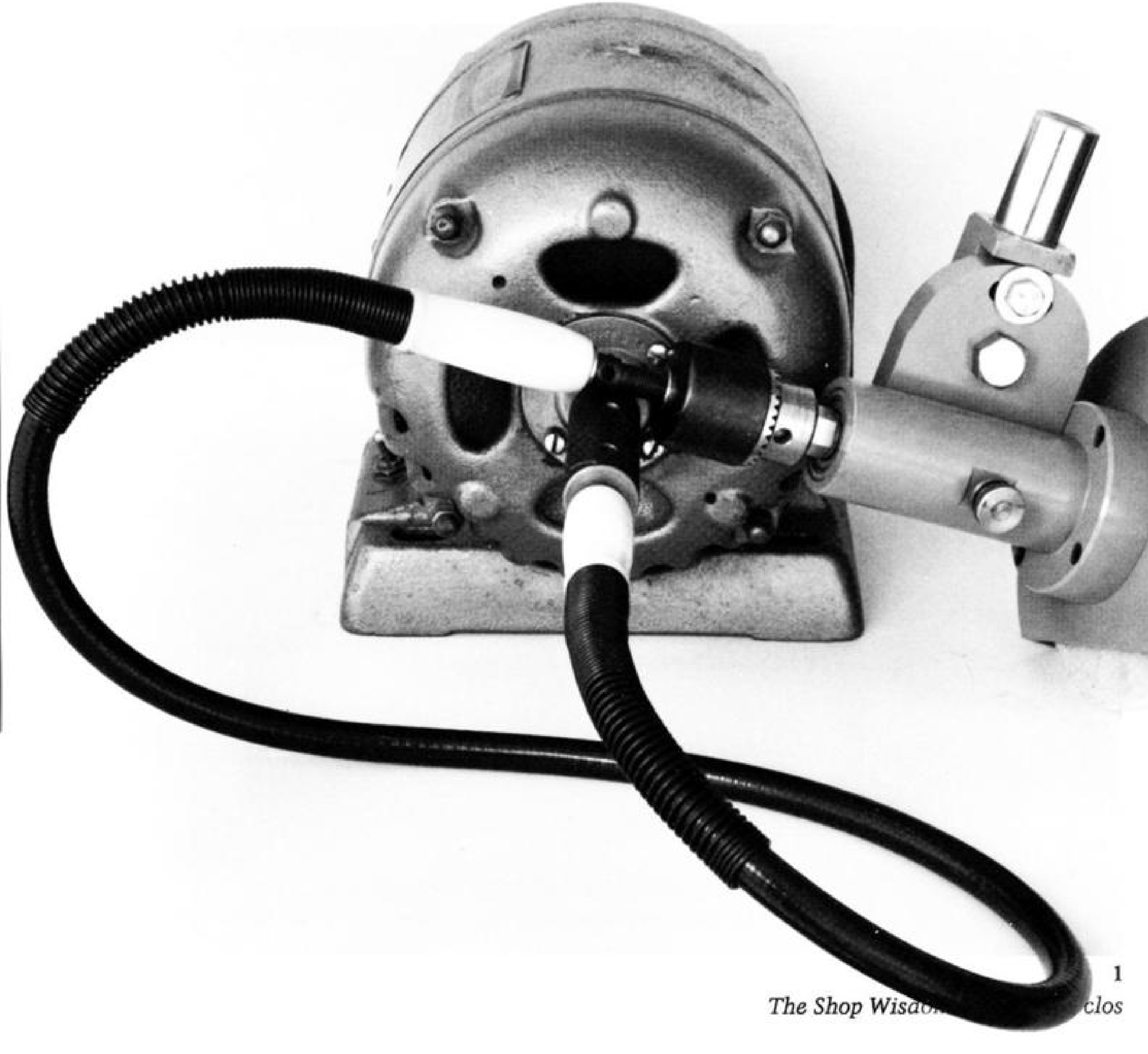
While grinding you *must* keep one hand on the rear end of the spindle to keep the rear stop collar in contact with the fixture body. When sharpening a four-flute, caution must be used as you approach the center line of the end mill. Don't allow the side of the wheel to plow into one of the other cutting edges. Now move the wheel back along the edge just sharpened until it clears the side of the end mill. Pull back on the spindle until the end mill clears the support finger. Index to the next flute, push forward on the spindle and repeat the process. If further sharpening is required, advance the longitudinal travel of your mill table by .001" and repeat.

To arrive at a 2° inward slant on the cutting edges of a six-flute mill, the fixture must be swiveled to about a 15° angle (Photo 27). The cutting edge to be sharpened must be tilted upward as in Photo 30. The amount of tilt is correct when the next cutting edge *above it* is in a vertical position. As you grind, watch that the side of the wheel doesn't plow into that vertically positioned tooth. After sharpening the six-fluter, check the 2° inward cutting angle. Lay a flat piece of metal over the end of the cutter and verify that only the outer tip of each tooth is touching the flat. If not, readjust that 15° angle of the fixture.

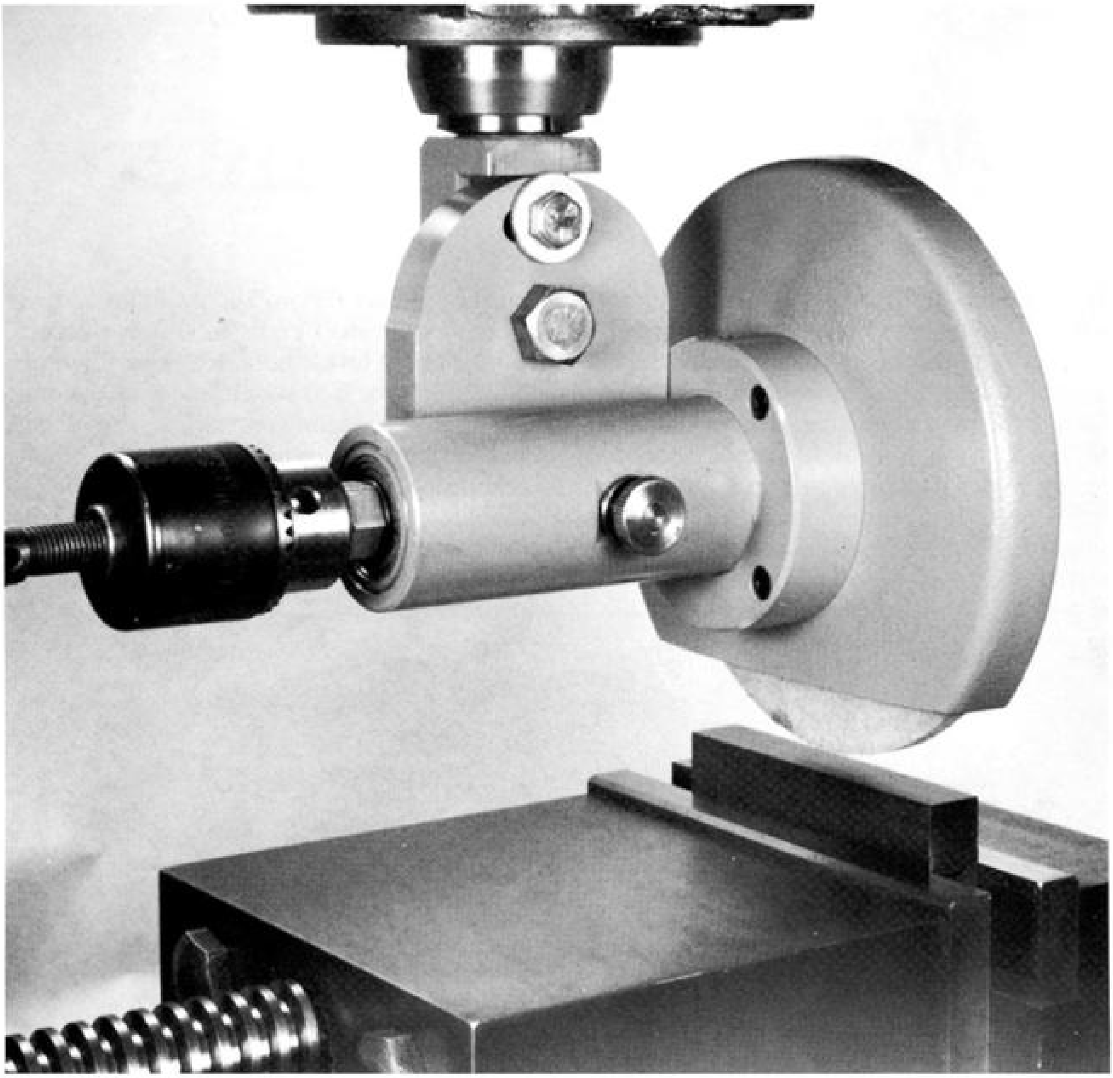
The performance of this "floating" end mill sharpener is even better than I expected. It's *almost* fun to use! A 1½" diameter end mill is as easy to sharpen as a ⅛" one. I suspect that smaller ones could be sharpened – however, I didn't have enough courage to try it!

Unorthodox Mill/Lathe Grinder

A lathe tool post grinder is an item that most of us won't use every day of the year – but it certainly comes in handy when you need it. How does the obnoxious price of $800 or $900 for a *small* size grinder grab you? Well, not wanting to deplete my pocketbook, I came up with this unorthodox grinder (Photo 1). It's inexpensive, easy to make, and you'll be forever freed of slipping belts and under powered motors, traits all too common with tool post grinders. Best of all, this grinder can turn your vertical milling machine into a surface grinder (Photo 2). You'll need a heavy duty flexible shaft and a 3450 rpm electric motor of 1/4 hp or more. It's possible to use a 1725 rpm motor by mounting it and a countershaft on a wooden base; utilize a 2-to-1 ratio of pulleys from the motor to the countershaft and thus attain the 3450 rpm. Remember, too, that most flexible cables are designed to operate (under power) in a clockwise direction; make sure you attach the cable to a motor or countershaft that rotates clockwise.



1



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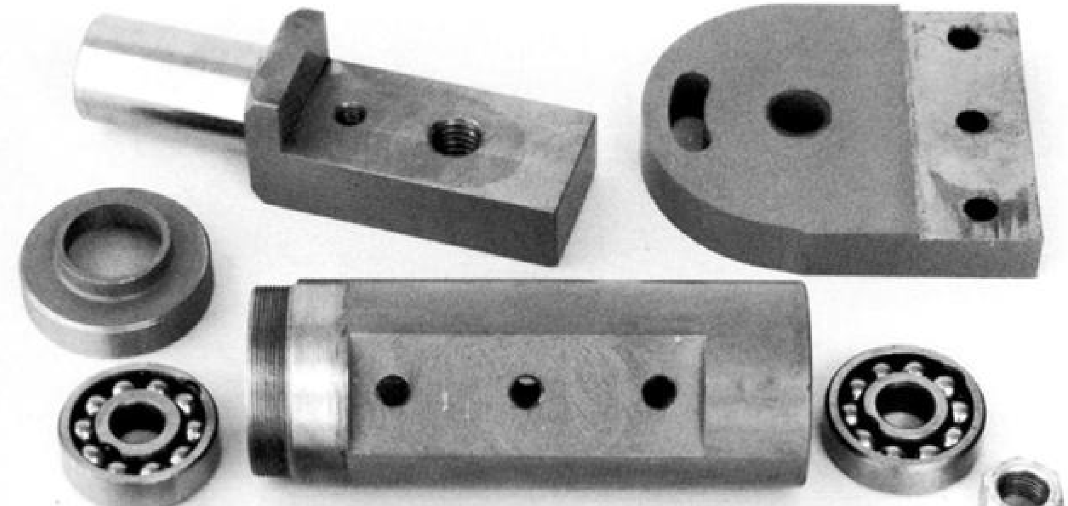


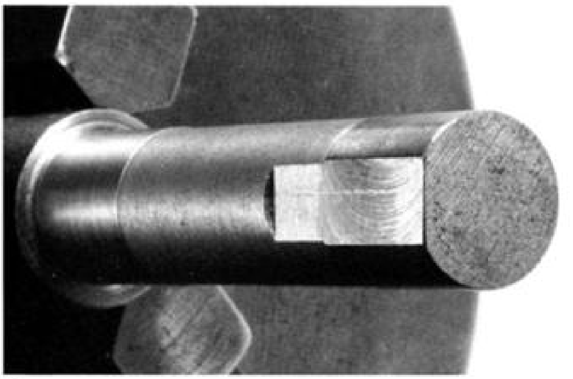
3

When designing a grinder to fit your size of lathe, keep in mind that the center line of the grinder spindle should line up horizontally with the center of the lathe spindle; however, if it's off a little, the only harm done is that the graduated collar readings on your cross slide will be slightly inaccurate. If you are grinding a bevel, the degree readings on the compound slide will also be slightly off.

My grinder was made to fit a forty-year-old 12" Clausing lathe. Usually I use it with a 5 × 1/4" wide grinding wheel. Let's briefly review some of the machining procedures involved in making the grinder. The ball bearing housing was machined from a round steel rod 1-1/2" in diameter by 4" long. It was chucked up in a three-jaw chuck with one end exposed about an inch. Face off the end, center drill it and proceed to drill a 3/4" hole all the way through the housing. Now, using a boring bar, clean up the hole so that it runs true all the way through the housing. The next step is to counterbore the recess for one of the bearings. The new bearings I used were purchased at a swap meet for 50¢ each; their OD is about 1-3/16" and the ID is a little over 3/8". The ideal diameter of the bearing recess should be about *.0001" smaller* than the bearing OD. Please note: the foregoing dimension is 1/10" *of a thousand.* Any overall dimension smaller than this might create immense compression on the bearing, causing it to stiffen and possibly freeze up when in use. On the other hand, the bore should *never* be larger than the bearing diameter; at worst it could be the *same* diameter. The depth of the bearing recess is approximately equal to the width of the bearing. Now machine down a 1/4" length on the end of the housing to a diameter of 1-1/4"; then thread this portion, as it will be used to accommodate a dust cap over the spindle on the grinder side of the housing. I used 32 threads per inch; refer to Photo 3. Remove the workpiece from the chuck.

A flat section must now be milled on the bearing housing to accommodate the baseplate. I used a 1/2" piece of steel 2-1/2" wide by 3" long for the baseplate; thus the flat on the housing should be 2-1/2" long by about 1/8" deep. Three 1/4-20 Allen cap screws are used to hold the baseplate and housing together; of course the heads of the screws must be completely countersunk below the surface of the baseplate. More about the baseplate later. For now, remove it from the housing.

The second bearing recess in the housing must be absolutely in line and parallel with the first – don't just plop the housing into your three-jaw chuck and hope for the best! Machine it on a stub mandrel. The mandrel illustrated in Photo 4 is actually a dual purpose mandrel; that is, it can hold the workpiece by two different methods: First, by the "self-locking" method as described elsewhere in this book. Second method: Simply hold the housing in place by using a setscrew in one of the three holes intended for the baseplate. Photo 5 shows both locking methods being used, but of course only one is necessary. Due to the rather long overhang distance of the housing from the chuck, take light cuts as you bore the bearing recess.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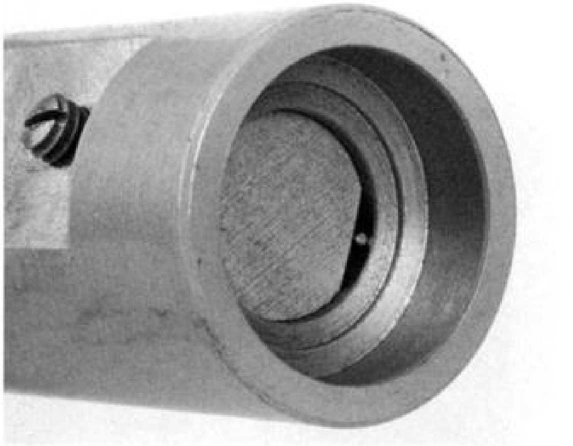
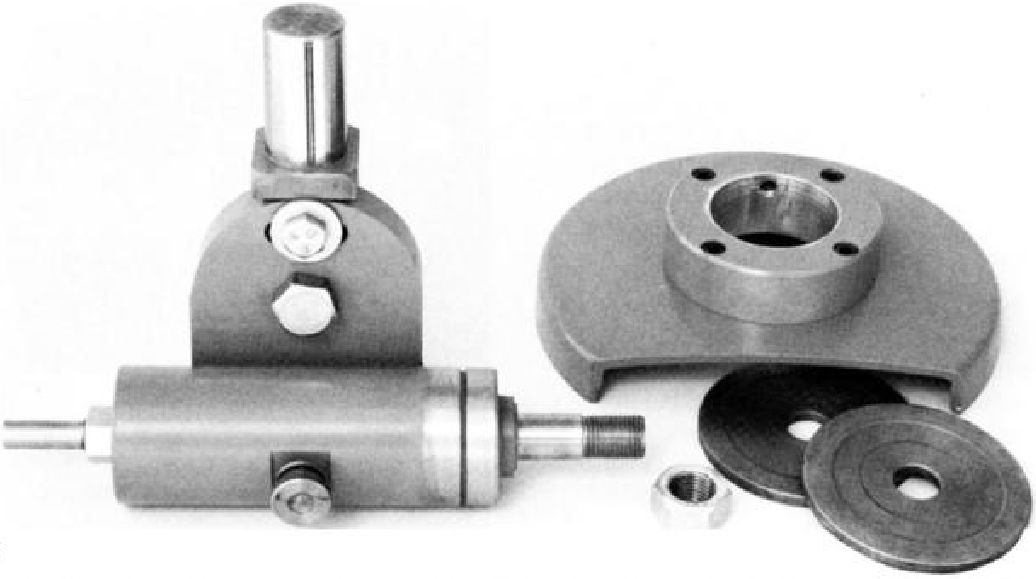

5

Since the bearings I used have grease covers only on one side, it was necessary to provide an oil hole in the housing, and also a threaded plug to keep grit out of the hole. This plug is nicely visible in Photo 12. If your bearings are sealed on *both* sides, an oil hole is not necessary.

The spindle (Photo 3) was made from a 3/4" mild rod about 7" long and was machined between centers. The grinding wheel end is .500" in diameter by 1-3/8" long with a standard 1/2-20 thread machined on the end for

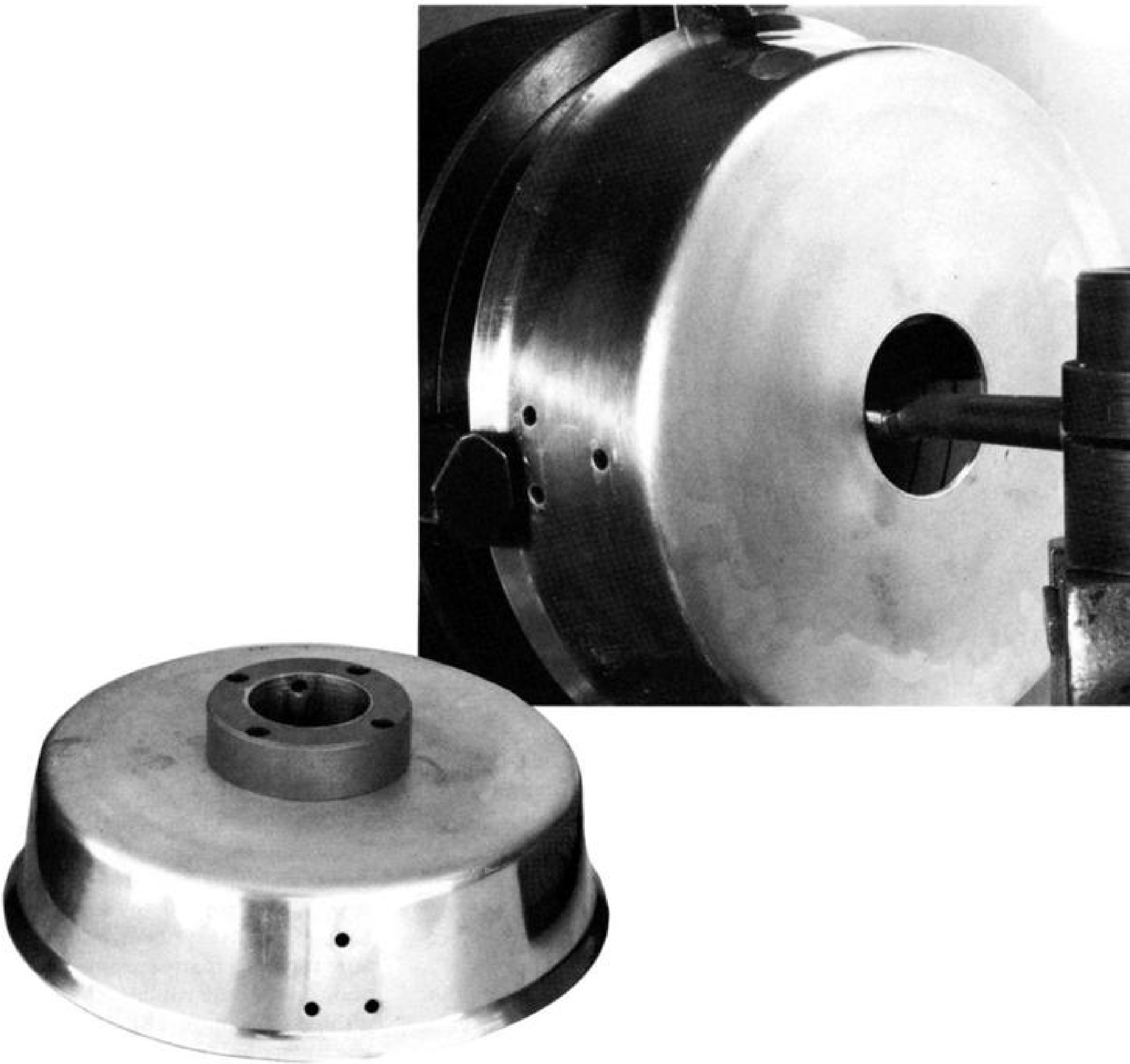


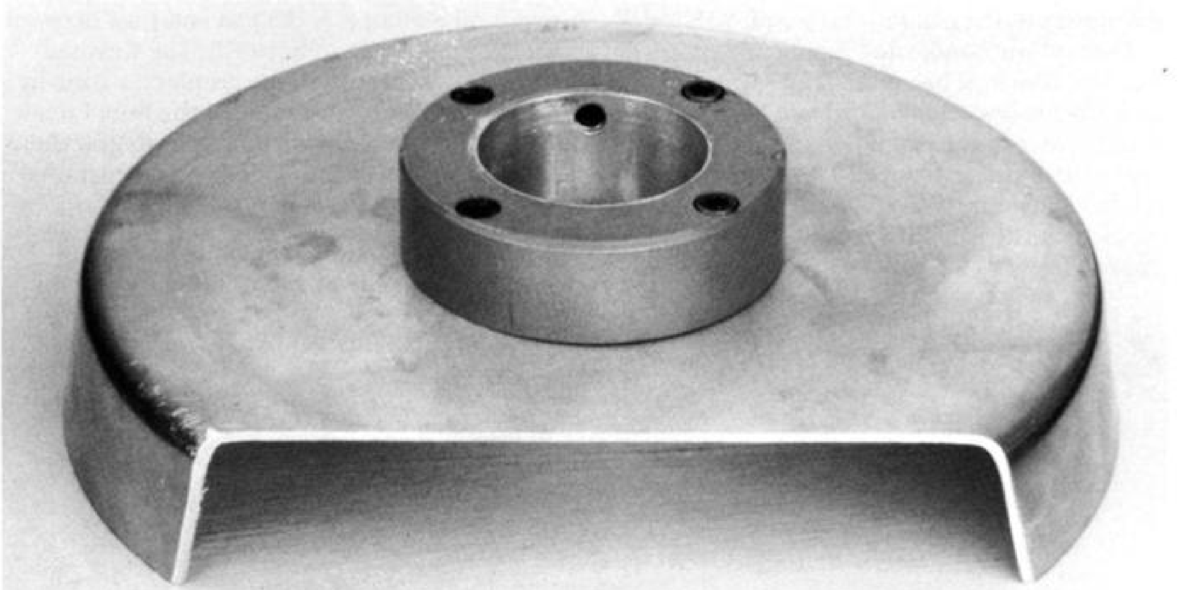
6

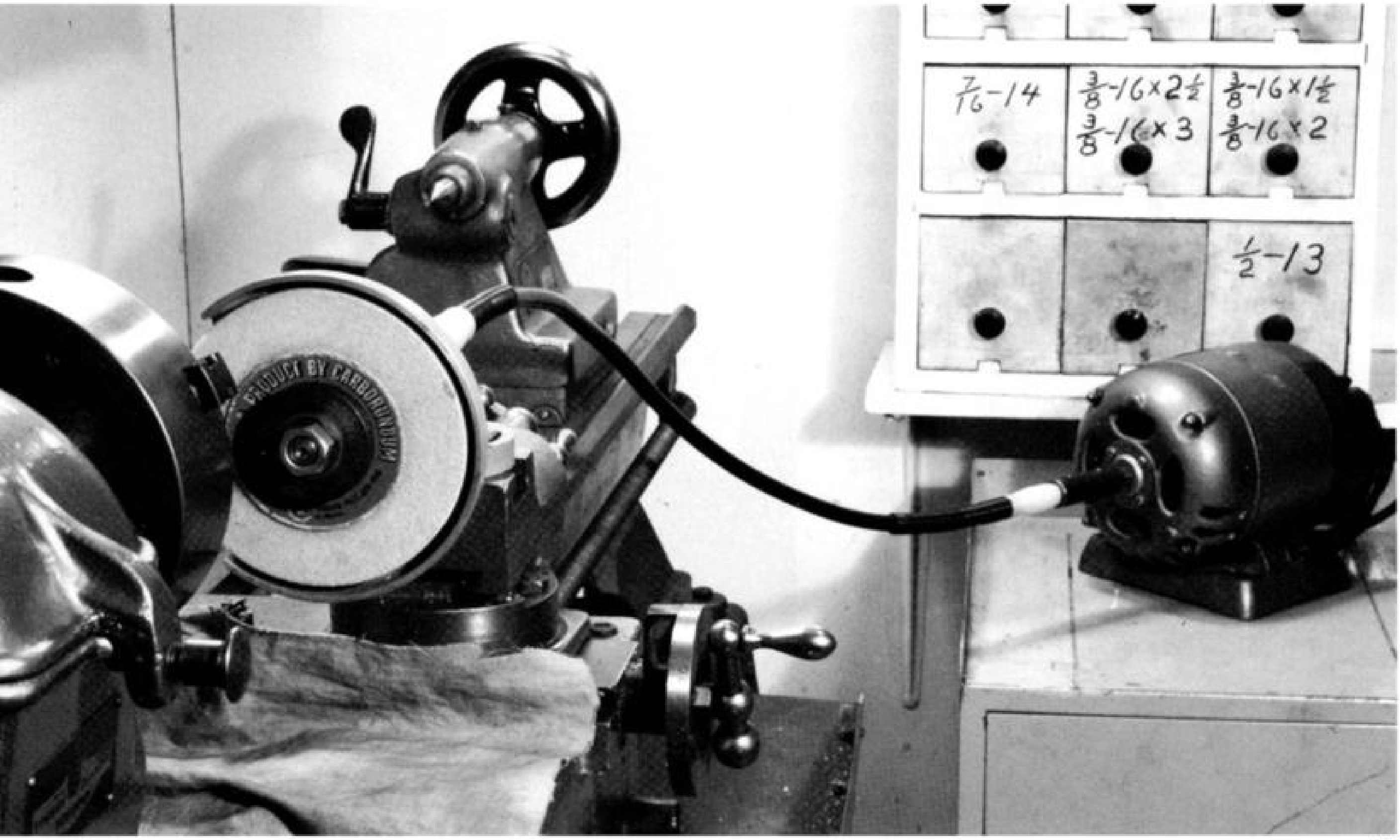
7

distance of about 11/16". As with the fit of the bearings in the housing, so too should their fit on the shaft be just a light press fit. In the photograph, the two blackened areas on the spindle indicate where the bearings will rest; reduce the diameter of the section in between by .002" or .003"; thus the task of getting the shaft through both bearings is eased. One can imagine the fireworks that would occur if the spindle, while in use, took a notion to slide partially out of the housing. So a 3/8-24 thread must be cut on the shaft behind the back bearing and a safety nut snuggled against the bearing itself. This will prevent any impromptu wanderings on the part of the spindle. Machine the remainder of the shaft to a diameter of 5/16".

To install the spindle, first press the bearings into each of the housing; then press the spindle through the housing until the shoulder collar is seated against the front bearing race. At this point you may find that the spindle turns rather stiffly. It's due to the side pressure on the bearings caused by the press fit. So screw the spindle's "safety" nut. Tighten it snugly against the bearing, then loosen the nut a fraction of a turn. Now, using a soft mallet, hit the back face of the spindle a fair blow. This should free the bearings. If not, loosen the nut a fraction more and repeat the process.





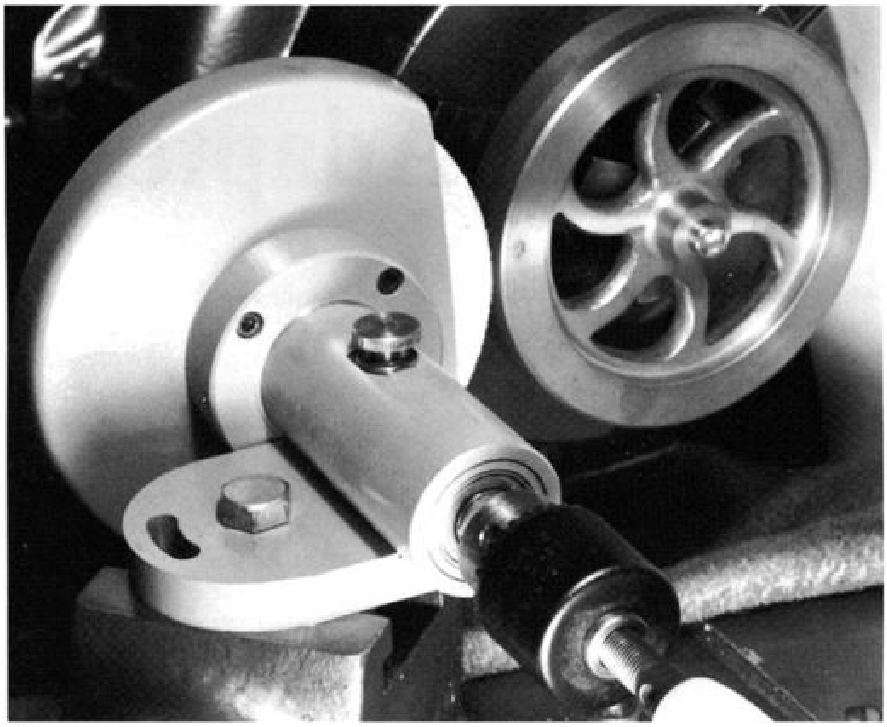


11

My scrap box produced a cast aluminum cover from a tank once used in an old hand-operated ice cream freezer. It made an ideal safety guard for the 5" grinding wheel (Photo 6). The hub for the guard was machined from a short piece of 2-1/2" aluminum rod, then bolted to the guard. When it came to finding something that could be used to make a guard for the 6" grinding wheel, I wasn't so lucky – I had to buy a 6-1/2" heavy gage (at *least* 1/16" thick) aluminum frying pan for that purpose (Photo 7). Discard the handle and mount the pan in a four-jaw chuck; it has more gripping power than a three-jaw chuck. Drill and bore a hole in the center of the pan (Photo 8); then fit it over a little stepped "locating" shoulder that you have machined on the hub. Bolt the hub in place on the pan with four 8-32 screws (Photo 9).

Incidentally, when machining, drilling, or tapping this soft type of aluminum, be sure to use a cutting fluid designed for aluminum; if it's not available, soapy water works fine, but to prevent rust spots on your machinery, be sure to wipe off any surplus water that splatters about. With the pan attached, hold the hub in a three-jaw chuck. Use a cutoff tool to remove the unwanted portion of the pan, leaving it about an inch deep. A hacksaw was employed to cut off a section of the pan and thus exposed the grinding wheel (Photo 10). The finished guard is held secure to the grinder housing by a setscrew through the side of the hub. I made steel flanges 1-11/16" in diameter to grip the 5" grinding wheel; 2-1/2" flanges are installed when using the 6" wheel.

When in use on either the lathe or milling machine, the grinder motor is positioned on



12

a side stand or bench (Photo 11). I just place mine there; it's not bolted down, and does not rattle or jump about. Perhaps the reason for this is because it's one of those wonderful old motors that is equipped with a large cast iron base. (They don't make 'em like that anymore.)

A few words about vibration. It can make the difference between a smooth, accurate finish and a rough, gouged surface. First, the grinding wheel should run as true as possible. Using a diamond dresser, always face off the periphery of the wheel straight and parallel before grinding. Vibration from the motor driving the grinder is of little concern to us since the motor itself is not bolted to the lathe or mill; but the chuck on the flexible cable could cause trouble. The flexible cable I purchased was equipped with a small drill chuck threaded on one end. This chuck turned out to be about the worst example of a chuck I've ever seen. It really set up a vibration when hooked to the grinder. Luckily, I was able to "borrow" a fairly good chuck from my electric hand drill. If you have the same problem, the best way to solve it would be to eliminate the chuck entirely and make a true running adapter sleeve. One end of the sleeve would fit snugly over the grinder shaft and the other end would be threaded 3/8-24 for the cable end to screw into. A setscrew through the side of the sleeve would secure it to the grinder shaft; be sure to file or mill a small flat on the grinder shaft where the setscrew makes contact. The adapter sleeve for the motor is similar – a hole in one end to fit the motor shaft and a snug fitting hole on the other end for the cable shaft. Two setscrews will hold the unit in place.

Remember, the purpose of surface grinding, or using a grinder on a lathe, is for *precision* work. Don't try to remove a lot of metal in one swipe. Take it slow and easy; limit the depth of the cut to .001" at a time, or better yet, to .0005". Otherwise, you'll soon dull the grinding wheel and overheat the workpiece. Always wear protective goggles.

Old Lathe Collet Adapters

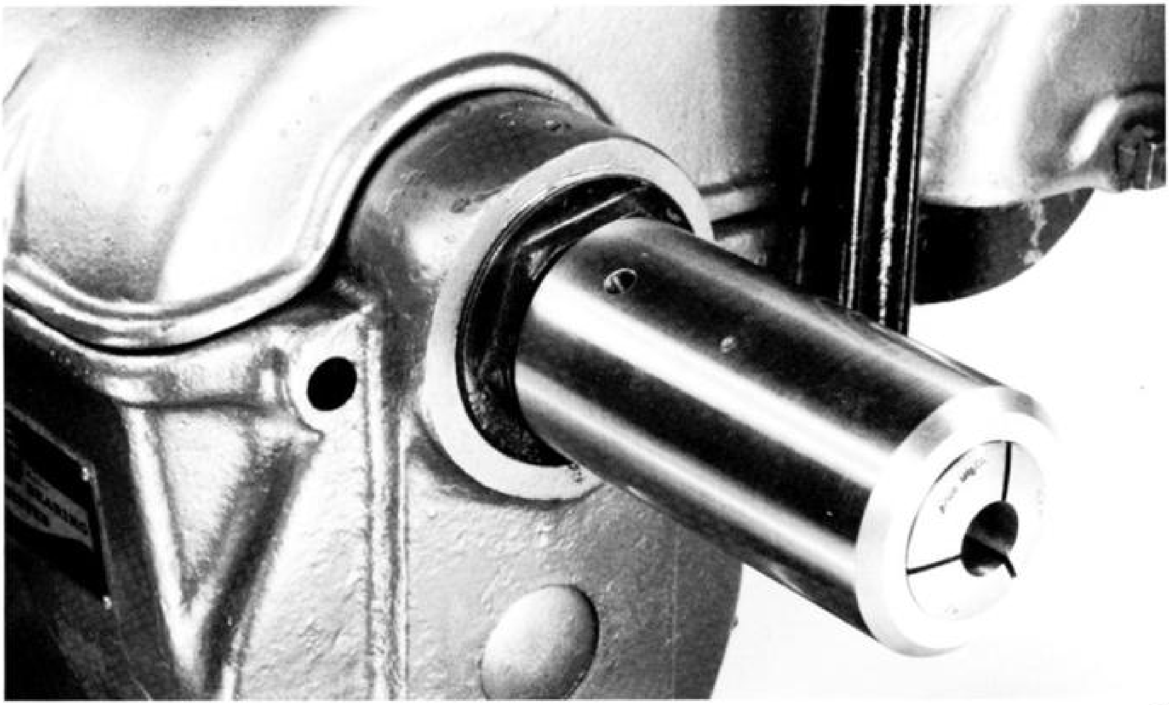
Speaking of old lathes, my 12" Clausing lathe must be at least 40 years old. The bore through the headstock spindle is a dinky 3/4". Today's comparative lathes would have at least a 1-3/8" bore, hence no problem adapting 5-C collets to them.

This method of using 5-C or even R-8 collets in an old lathe is relatively simple and easy to construct (Photo 1). I became so carried away I made two adapters, one for the 5-C collets and the other for R-8 collets (Photo 2).

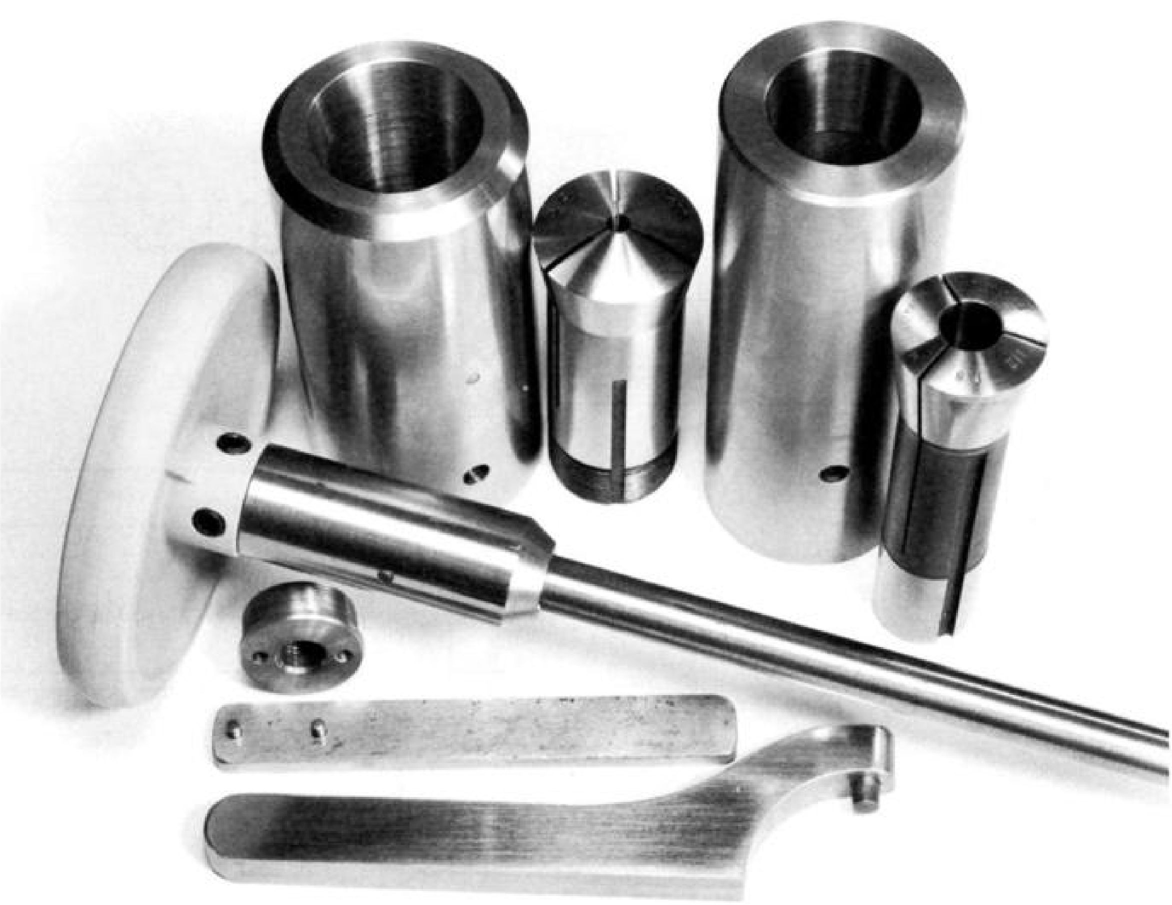
In use, a special threaded plug must be inserted into the back end of the 5-C collet (Photo 3); thus, one drawbar can be employed for either type of collet. Since the drawbar is a solid rod, the insertion of long workpieces through the spindle is impossible. However, "half an apple is better than no apple at all"!

Before starting construction, carefully examine the spindle nose of your lathe. Of particular importance is the condition of the shoulder face (Photo 4). After many years of use (and abuse!) it's likely that the face is pockmarked with humps and hollows, so test it with a dial indicator. Any deviation in the reading is rectified by taking a very light, smooth cut across the face of the shoulder.

Chuck up the workpiece for the 5-C collet sleeve as in Photo 5. Drill and rough-bore a hole about 1-3/16" in diameter all the way through; then counterbore and thread to fit your lathe spindle. As you thread, it's important to cut the threads for a snug fit on your spindle. Test fit by unscrewing the chuck (with the workpiece intact!) from the lathe spindle. Reverse it end for end and attempt to screw the workpiece onto the spindle – it's a matter of remounting the chuck and taking another light cut on the threads. Repeat the entire process until the sleeve will screw snugly onto the spindle. When this is accomplished, remove the work from the chuck. Now lay out and drill a blind 17/64" hole in the side of the sleeve for the spanner wrench. If you don't already have a suitable spanner wrench, it's necessary now to build one (Photo 6). I cut mine from a piece of 1/2 × 1-5/8 × 6" hot rolled steel. Use a 2" fly



1

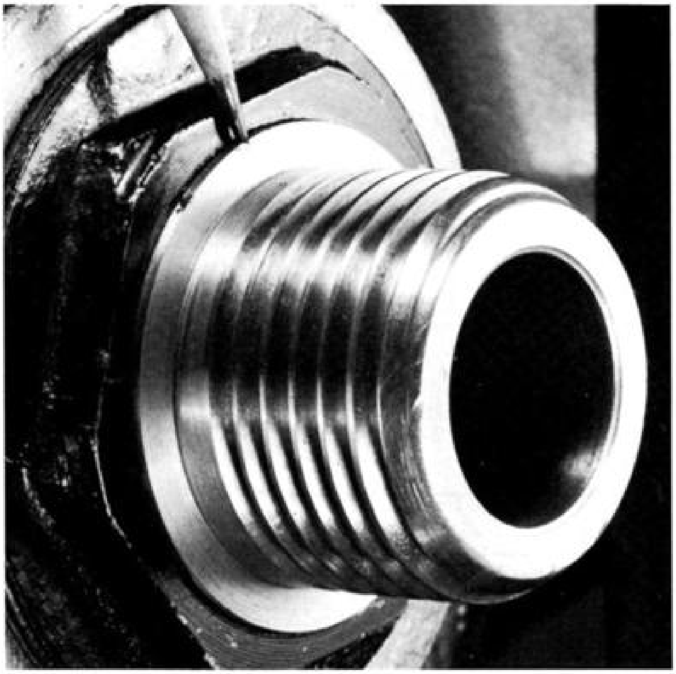


2

cutter or end mill to form the radius on the business end of the wrench (Photo 7). I employed a metal cutting band saw to rough out the rest of the contour. Photo 8 shows the finished wrench in position.

After completing the spanner wrench, it's time to finish the partially machined 5-C collet adapter. Screw the sleeve onto your lathe spindle and bore out the collet taper – leave it a little *undersize.* Now, as in Photo 9, draw some chalk lines on the taper. Insert a 5-C collet using a twisting motion when it's seated. Remove the collet and examine the chalk marks in the sleeve to determine where they've been

3



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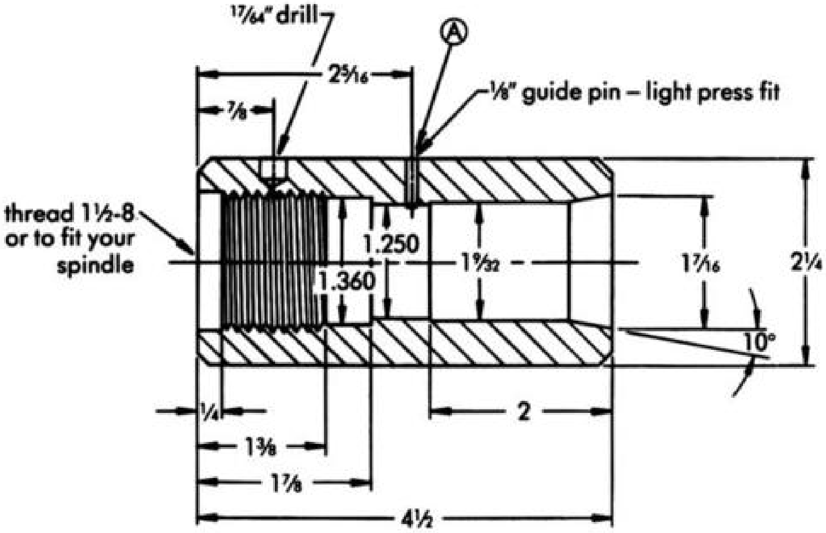
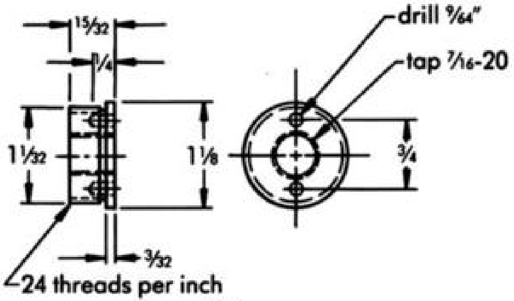
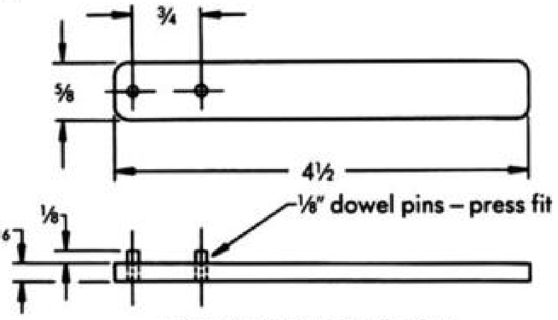

17/64" drill
2 5/16
A
7/8
1/8" guide pin – light press fit
thread 1½-8 or to fit your spindle
1.250
1.360
1 9/32
1 7/16
2¼
10°
¼
1⅜
2
1⅞
4½

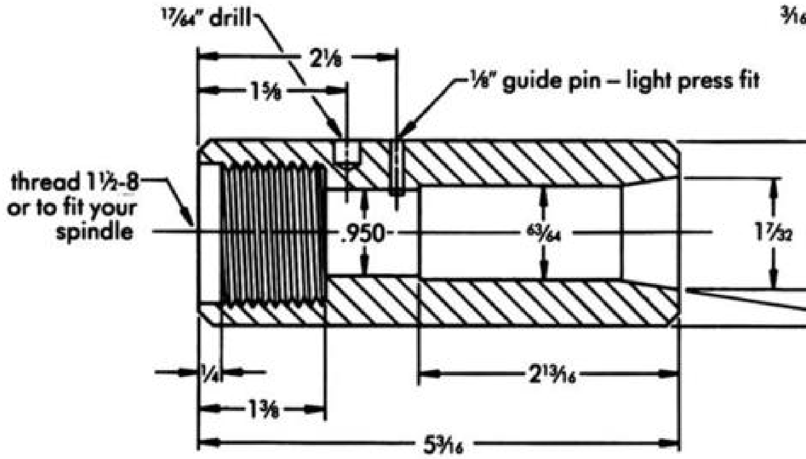
5-C COLLET SLEEVE


15/32
¼
drill 9/64"
tap 7/16-20
1 1/32
1⅛
¾
3/32
24 threads per inch

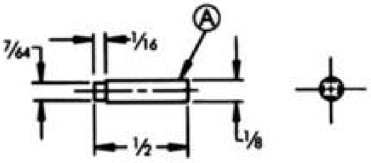
5-C COLLET PLUG


¾
5/8
4½
1/8
3/16
1/8" dowel pins – press fit

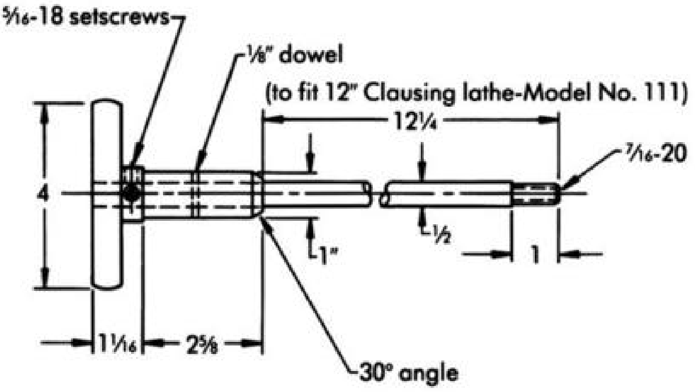
5-C COLLET PLUG WRENCH

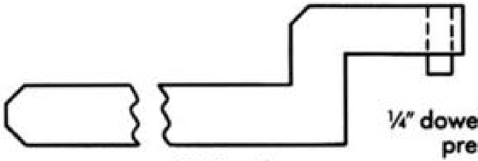

17/64" drill
2⅛
1⅝
1/8" guide pin – light press fit
thread 1½-8 or to fit your spindle
.950
63/64
1 7/32
2
8½°
¼
2 13/16
1⅜
5 3/16

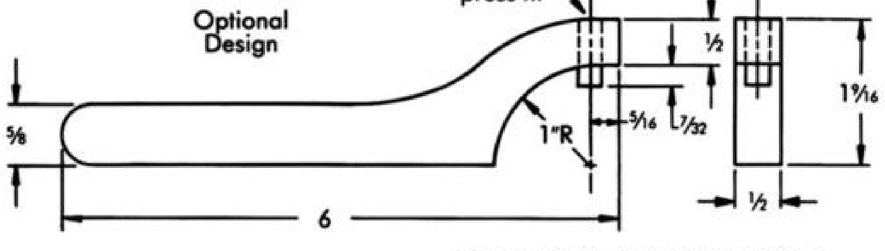
R-8 COLLET SLEEVE


A
7/64
1/16
½
1/8

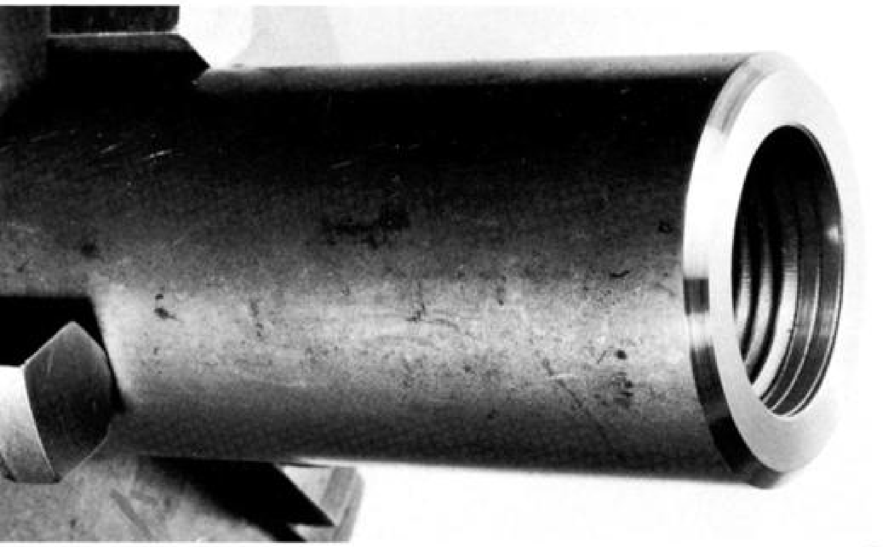
5-C PIN


two 5/16-18 setscrews
1/8" dowel
(to fit 12" Clausing lathe-Model No. 111)
12¼
7/16-20
4
1"
½
1
1 1/16
2⅝
30° angle


Optional Design


¼" dowel pin press fit
½
1 9/16
5/8
1"R
5/16
7/32
½
6

COLLET SLEEVE SPANNER WRENCH



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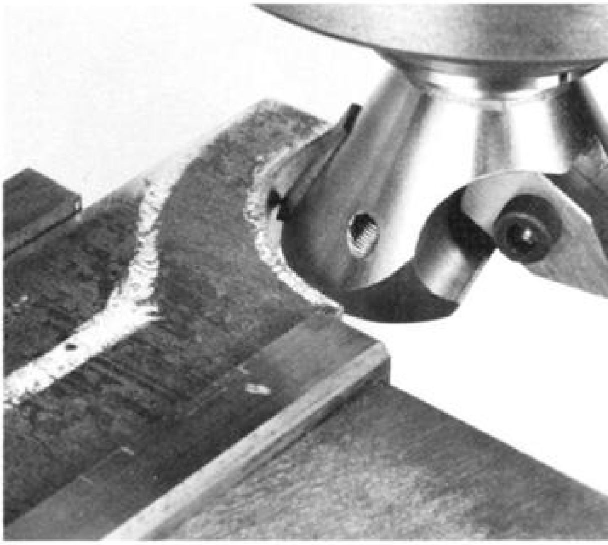

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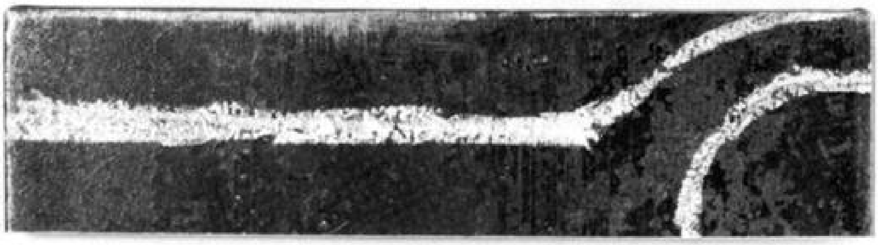
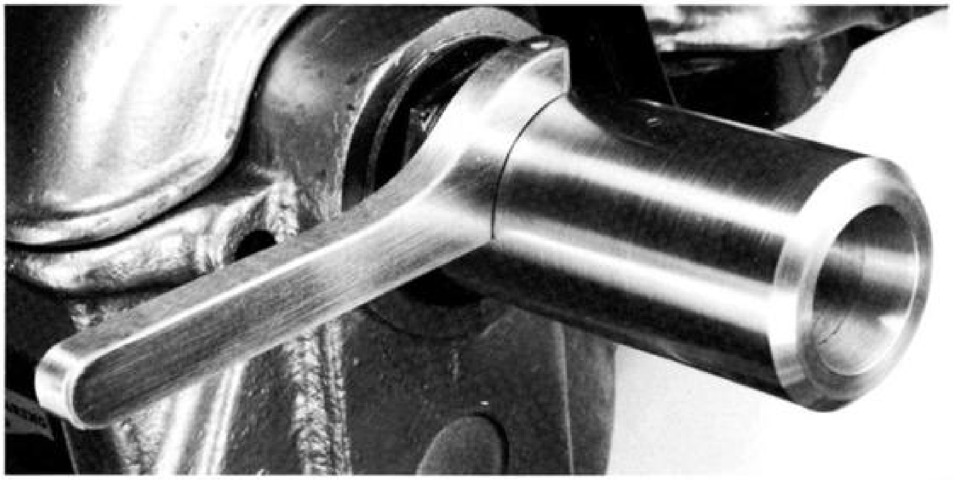


6



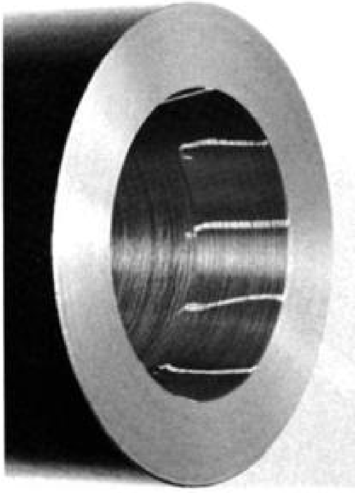
8

disturbed. Usually it's necessary to adjust the compound angle several times before a fairly even smudging of the chalk lines is achieved. Then finish the taper to size. Finally, take a light cut along the outer length of the sleeve to true it up. Remove the work from the lathe, lay out and drill the 1/8" guide pin hole through the sleeve.

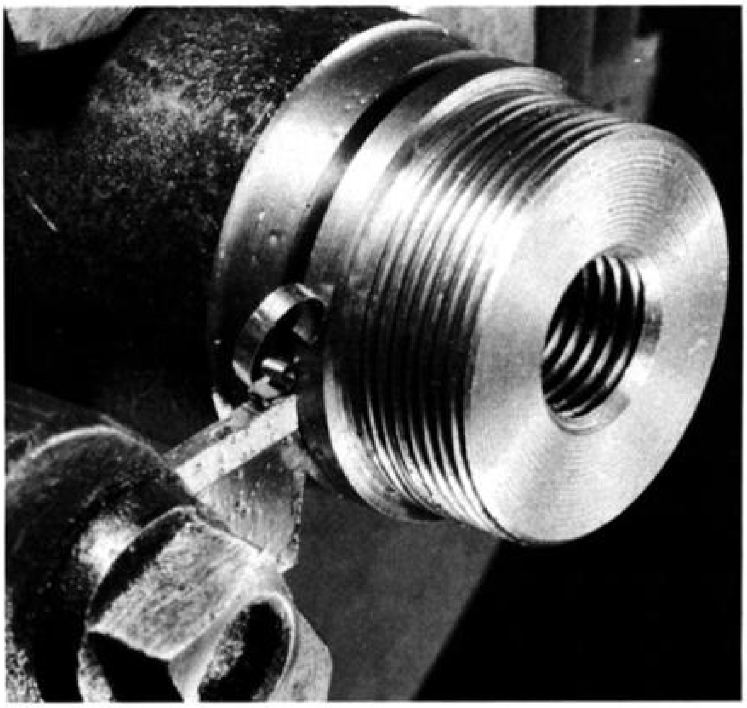
When making the guide pin for the 5-C sleeve, it's necessary to step cut one end to a diameter of 7/64". When the pin is pressed into position in the sleeve, this 7/64" diameter end must *not* extend into the inner bore more than 3/64".

If you make an R-8 collet sleeve, the guide pin does not need a step cut on it as the groove in the R-8 collet is slightly wider than the 5-C.

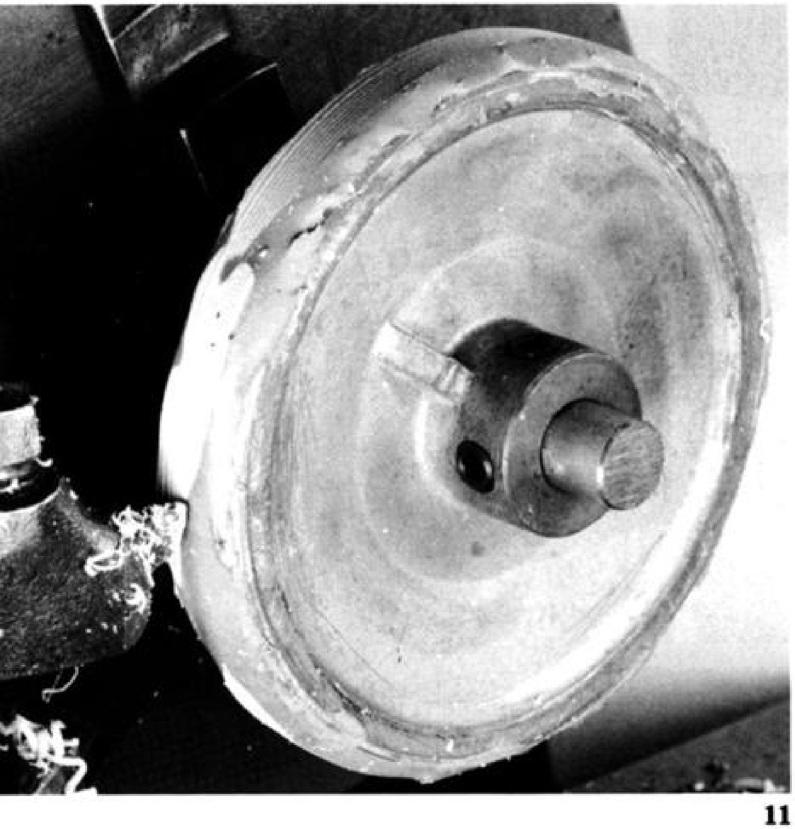
The 5-C collet plug is easily machined as in Photo 10. When cutting the threads on its OD to proper size, be sure to try every 5-C collet you have to make certain that each one will screw onto the plug properly. Now build the little 5-C collet plug spanner wrench.



9



10



11

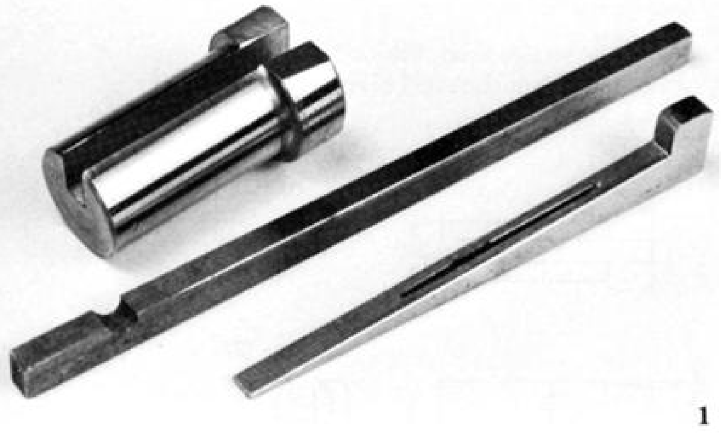
Several options are available when constructing the collet closing drawbar. I used an old 4" die cast V-pulley for the handwheel (Photo 11). The V-groove in the pulley was filled with auto body plastic filler and, after hardening, was machined to form a convex outer rim. If you use this method, be sure to install two 5/16-18 setscrews in its hub; also file two mating screw flats near the end of the drawbar shaft. Another option is to machine the handwheel from a solid piece of steel; or if you have a 3" long piece of hexagon bar stock, you could simply drill a 1/2" hole lengthwise through it and pin it onto the drawbar shaft. An end wrench would be employed to tighten the collet.

In determining the correct length of the drawbar for your lathe, remember that the front end of the drawbar should screw into the back end of the collet about 1/2" *before* the drawbar begins to exert pressure on the collet.

"Slow Poke" Small Keyway Broach

A set of small keyway broaches costs about $85-$90, which is probably fair enough – but if you only have one or two keyways to cut, this price will cause you to stop and think. So, after a period of cogitation, I came up with the "Slow Poke" keyway broach. As things turned out, it was such a fun project I ended up making *three* different size broaches.

Shown in Photo 1 are the three parts that constitute a "Slow Poke" – the guide, the cutter, and the wedge. Operation is simple; the bushing and wedge allow only an upward or downward movement to the cutter. Each pass of the cutter through the workpiece takes off about .002" of metal. The cutter and wedge are then repositioned and the process repeated until the proper keyway depth is reached.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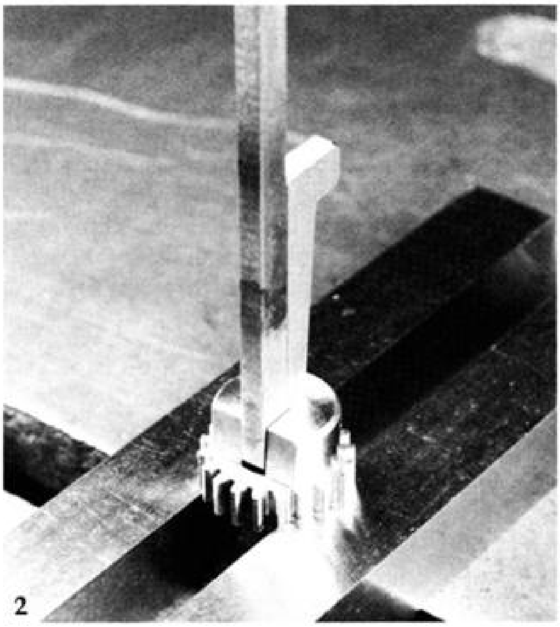
Calling this broach a "Slow Poke" is quite appropriate. A standard small keyway broach, which has perhaps 18 cutting teeth, needs only one or two passes through the workpiece to complete the job. Since our broach has only *one* cutting tooth, it's necessary to push it approximately 30 times through the hole to make a ⅛" keyway. Of course *fewer* passes are required for smaller keyways. This slowness is offset by the fact that the "Slow Poke" requires only about ⅕ the force to make a cut as a regular broach. An ordinary drill press can safely be used as an arbor press (Photo 2). Furthermore, *all* of the broach parts are made from cold rolled steel. Of course the cutter's tooth must be casehardened, but this is a very simple process. *Kasenit* hardening compound is easily obtainable. The "Slow Poke" performs beautifully.

Three cutters, ⅛" 3/32", and 1/16", are shown in Photo 3, together with three bushings, sizes ½", ⅜", and 5/16". A single wedge is used with all three setups.

Begin by machining the guide bushing. Turn out the bushing and head to size, but leave it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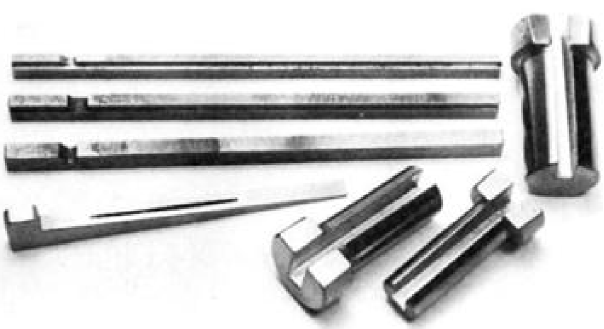
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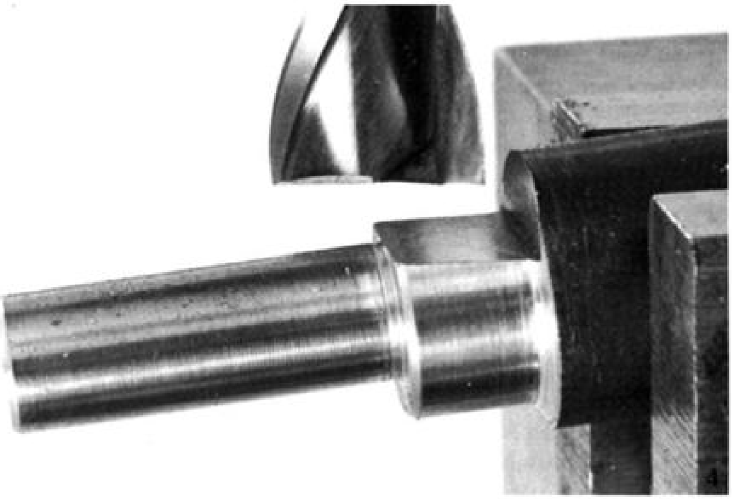

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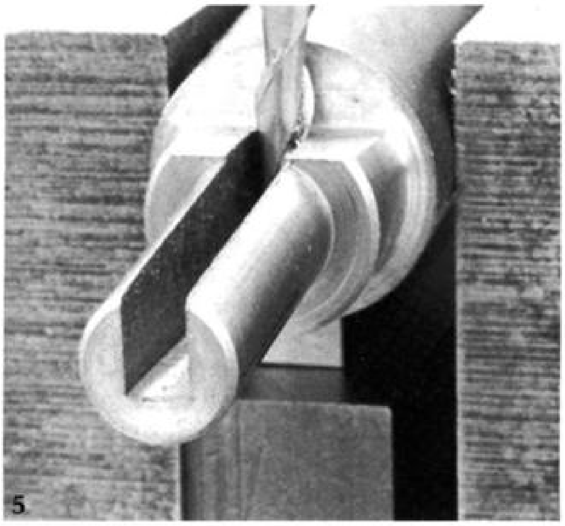

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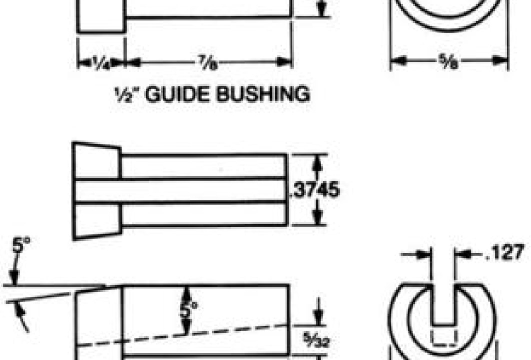
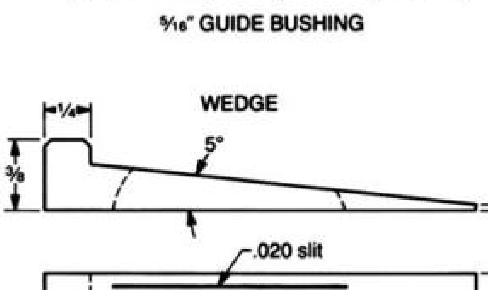
attached to the stock piece. At this point two milling operations must be performed. The workpiece is supported on a 5° angle block in a mill vise as shown in Photos 4 and 5. If you don't have a standard 5° angle block, one is easily made from a piece of steel about 3" or 4" long by ¼" thick and ½" wide; merely mill a 5° taper along the ¼" width of the piece. In any event it's important that the 5° angled slot milled in the guide bushing is *exactly* the same angle as that machined on the *wedge* piece – therefore use the *same* angle block for support when making each piece. Mill a flat on the bushing collar down to a point flush with the smaller diameter of the body (Photo 4). There's a dual purpose for this flat; first, a ⅛" end mill will be used to cut a slot the entire length of the bushing. Since standard ⅛" mills are rather short, it would be difficult to reach the required depth without the flat (Photo 5). Second, the flat affords good visibility during the broaching process. The depth of the slot at the *lower* end of the bushing should be about 13/64". After reaching this depth, move the end mill .002" to one side and widen the slot to .127". Now proceed to finish the bushing by parting it from the stock piece either with a hacksaw or with a cutoff tool in the lathe.

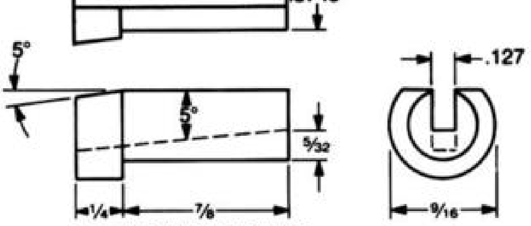
Make the wedge next. Photo 6 illustrates one way to position the steel blank for machining.



½" GUIDE BUSHING

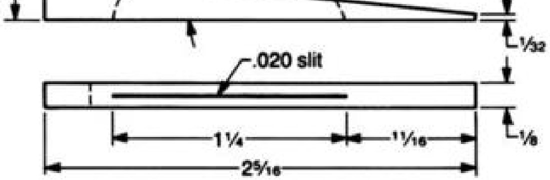


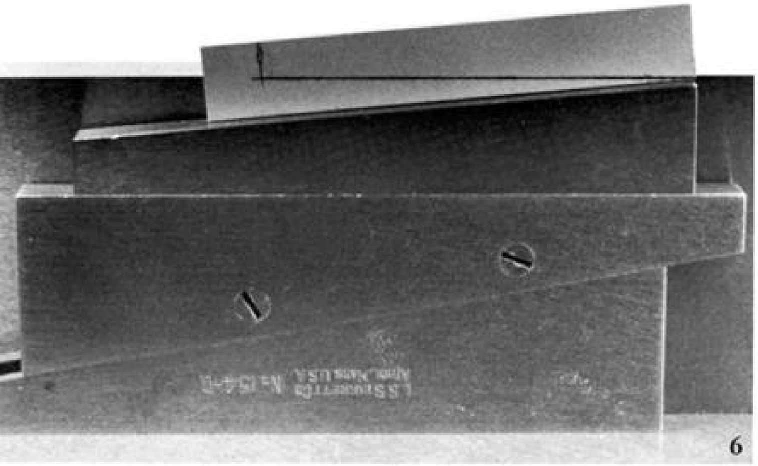
5/16" GUIDE BUSHING



⅜" GUIDE BUSHING

WEDGE





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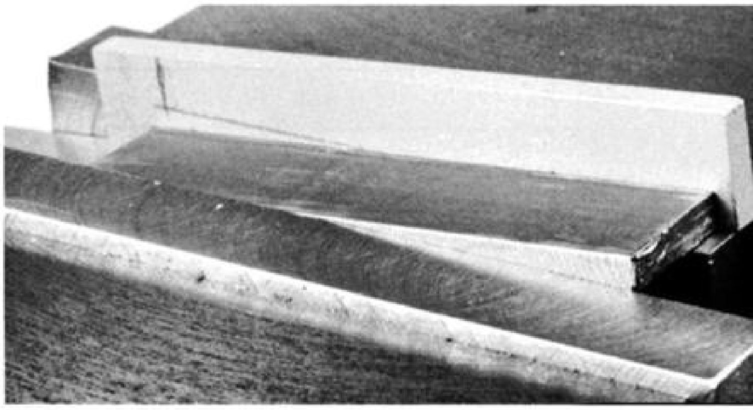

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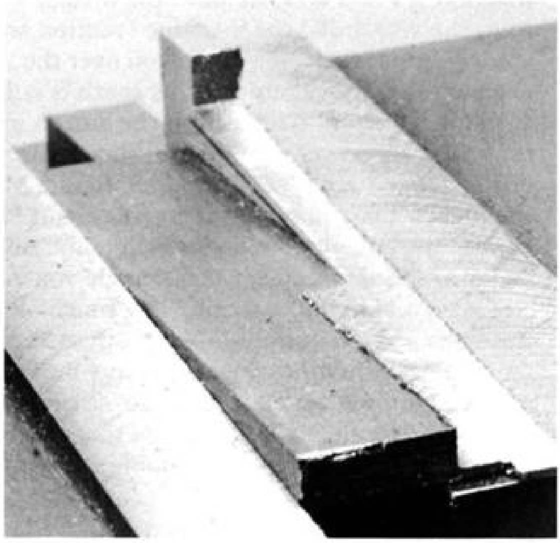

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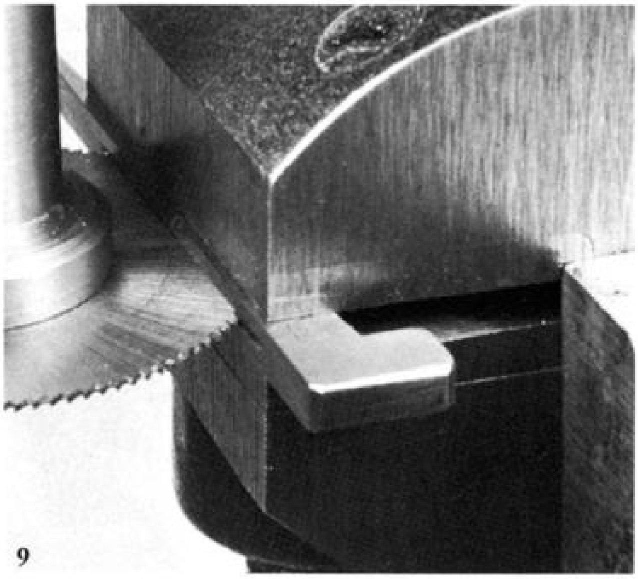

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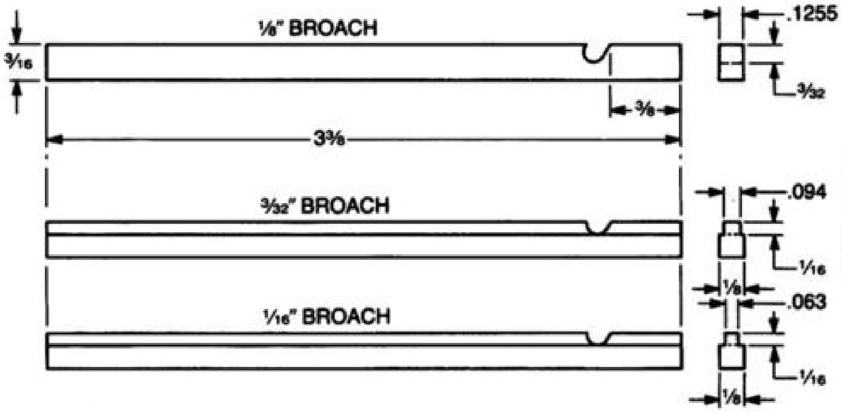
Use the same 5° angle block you used with the bushing. Naturally, the line to mill down to is slightly above the vise jaws. Now make a "sacrifice" parallel from a piece of cold rolled steel ⅛" thick, ½" wide, and about 2⅛" long. This will be used to clamp the workpiece securely in the vise jaws as in Photo 7. Now mill the taper on the wedge blank (Photo 8).

A thin slot about 1¼" long is cut through the center of the wedge (Photo 9). After slitting, force a small screwdriver blade into the slot to spread it apart slightly – just enough to make the wedge fit snugly in the bushing. This will prevent the wedge from slipping during the broaching operation.

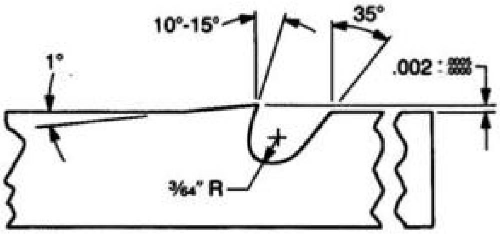
Fly cutting is the easiest method of forming the cutting tooth on the broach as shown in Photo 10; use an ordinary tool bit and grind it to the correct shape. Mount the broach blank in a mill vise at an angle of 10°-15° from the vertical. I prefer the 15° because it seems to ease the force required to broach. Fly cut the notch.

If you are making a 3/32" or 1/16" broach, it's necessary to mill down the ⅛" width of the broach body as in Photo 11.

In order for the broach to cut properly, it's essential to machine a slight top relief angle to the cutting edge. Mount the broach in the vise at a 1° angle; mill off *just* enough so the angle forms a sharp edge on the cutting tooth (Photo 12). Reposition the broach on a straight parallel in the vise. Now, in order to raise the height of the tooth about .002" or .0025" above the rest of the broach, it's necessary to remove that amount from both in front and behind the cutting edge. Start first on the longer section of the broach and carefully bring the end mill

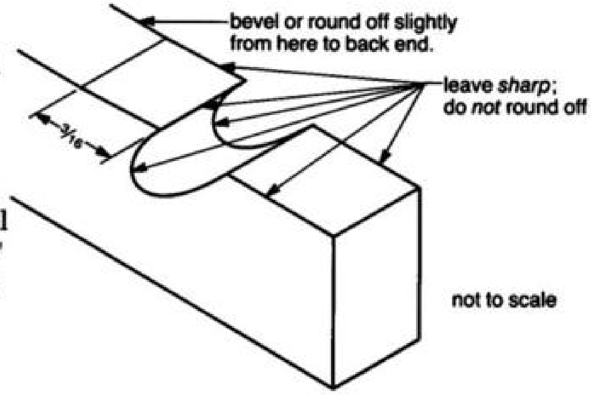


1/8" BROACH
3/16
3/8
3 3/8
.1255
3/32
3/32" BROACH
.094
1/16
1/8
1/16" BROACH
.063
1/16
1/8



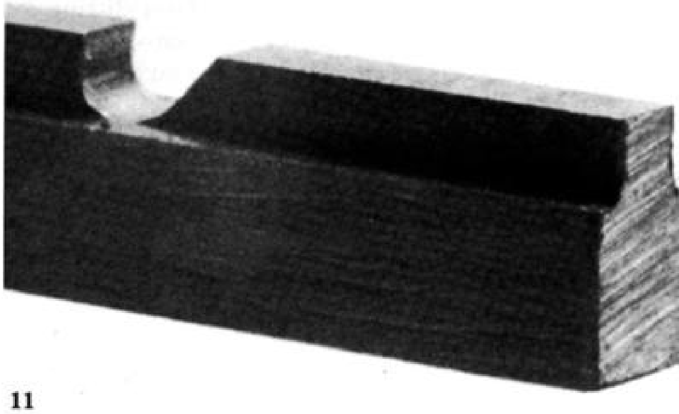
10°-15°
35°
1°
.002 :
3/64" R

down so that it barely scratches the surface; machine a small area. Remove the broach from the vise, mike the machined section and compare this with a reading taken over the cutting tooth. It's likely that the tooth is still too low, so carefully reposition the broach in the vise; then lower the end mill the required distance to obtain a .002" or .0025" figure. Mill the broach shaft, stopping at an area about 3/16" *behind* the cutting tooth, at which point your end mill should intercept the 1° angle you've already cut behind the tooth. Now finish off the short section in front of the tooth. After machining, *carefully* scrape away any burrs that have formed on or around the cutting edge of the tooth. The sides of the tooth as well as the top cutting edges should be *sharp* and clean.



bevel or round off slightly from here to back end.
leave *sharp*; do *not* round off
3/16
not to scale

Only the cutter end of the broach shaft is case hardened, a length of about 3/4". Don't be in a hurry to complete the process. Heat the first inch of the tool to a bright red (using an ordinary propane torch) then dip it in the *Kasenit* compound; immediately return it to the flame, keeping the broach end as hot as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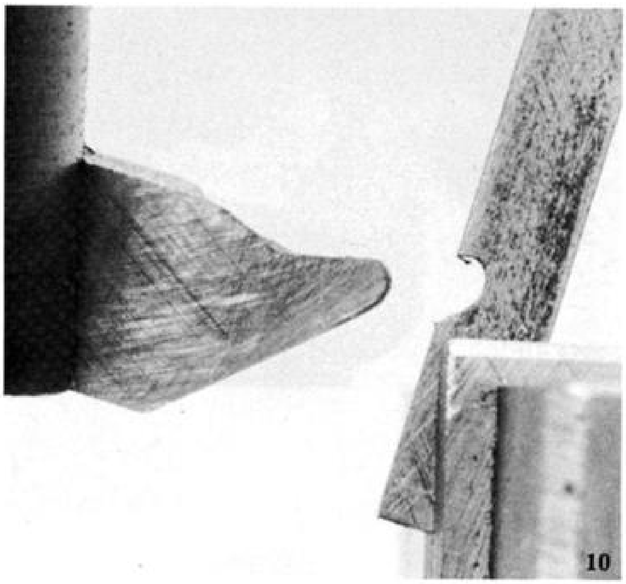
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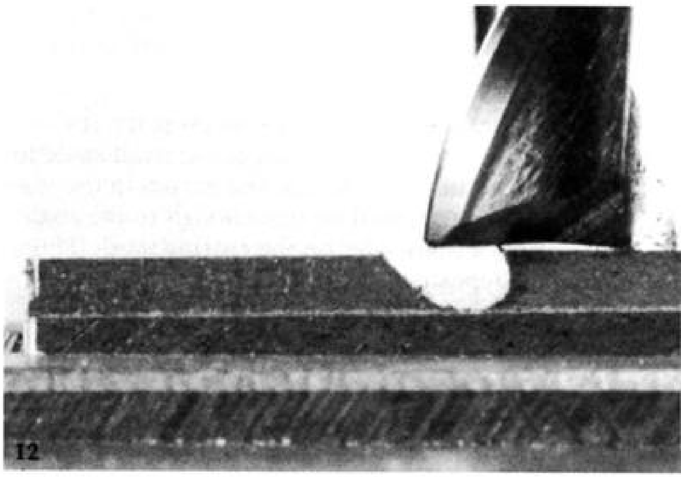
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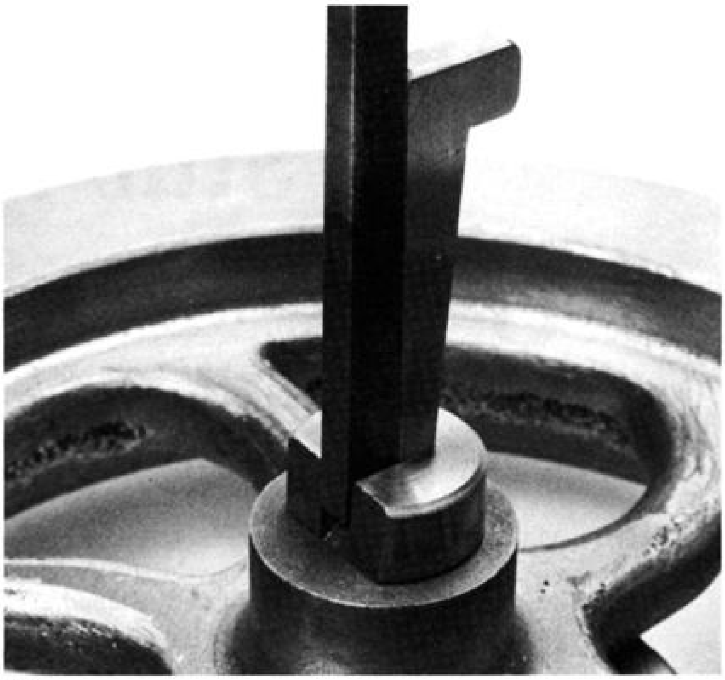
the torch allows, about 1600°. After 30-40 seconds again dip the piece in the *Kasenit* and then back to the flame. Repeat this several times. When it's ready to harden, plunge the broach straight up and down in plain water. *Don't* stir the piece around in the water – use only an up and down motion; this will minimize warpage.

To broach a hole, insert the guide bushing first; then follow with the wedge into the bushing slot, but only about ¾" of its length. Now the broach is pushed into the slot until its cutting tooth is about 1/16" above the hole to be broached (Photo 13). Using a finger or thumb, firmly push down on the wedge – this will force the pilot portion of the broach solidly against the wall of the hole. If you use your drill press for the broaching operation, be sure to center the work over a slot or hole in the table – no point in broaching the table too. You can use your *closed* drill chuck to do the pushing. Begin the broaching operation, but stop pushing *before* your drill chuck hits the wedge piece. After the first stroke, reach under the drill press table and pull out the broach. You'll discover that this first cut has produced only two little grooves in the hole. Reposition the broach in its guide bushing for the second cut, making certain that the two corners on the leading edge of the broach enter the grooves you have just formed in the workpiece. Again locate the cutting tooth just above the hole, firmly press the wedge into place and push the broach through the hole. If you are broaching steel, the addition of a few drops of cutting oil into the hole will help, but *don't* use cutting oil if the workpiece is cast iron or brass. Continue repeating the entire process until the keyway groove approaches the proper depth. You'll notice that the wedge piece is now quite low in the bushing (Photo 14). If you are broaching a ⅛" keyway, the depth of the keyway should be about .064". A fairly accurate way to measure the slot depth is to mike the height of the broach tooth above the guide bushing as in Photo 15. Be sure the wedge remains in the *same* position it was in during the last cut of the broach. Now remove the broach and wedge from the bushing and measure the bushing diameter – with one of the micrometer anvils straddling the slot. The difference between the two readings is the slot depth.



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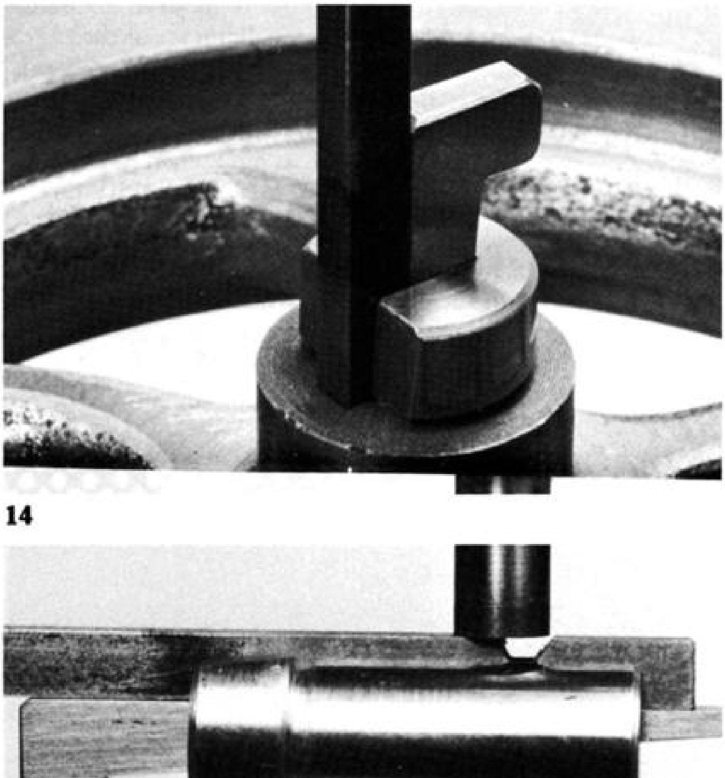

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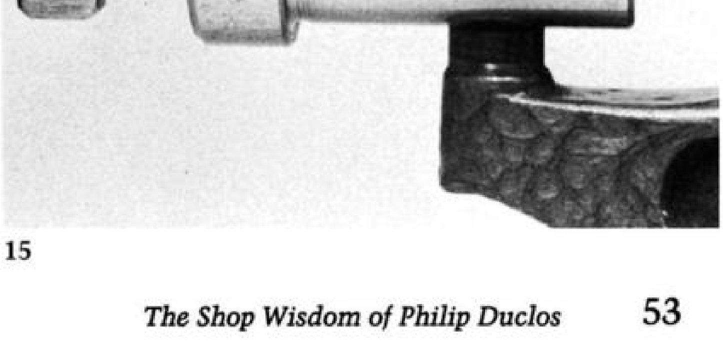

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Temporary Self-locking Stub Mandrel

Occasionally, the only way a piece of work can be machined properly is to mount it on a lathe mandrel. Who in the world owns a complete set of lathe mandrels? I pride myself on having a very well-equipped home workshop and, thanks to this simple little trick, I've never had to buy a single lathe mandrel.

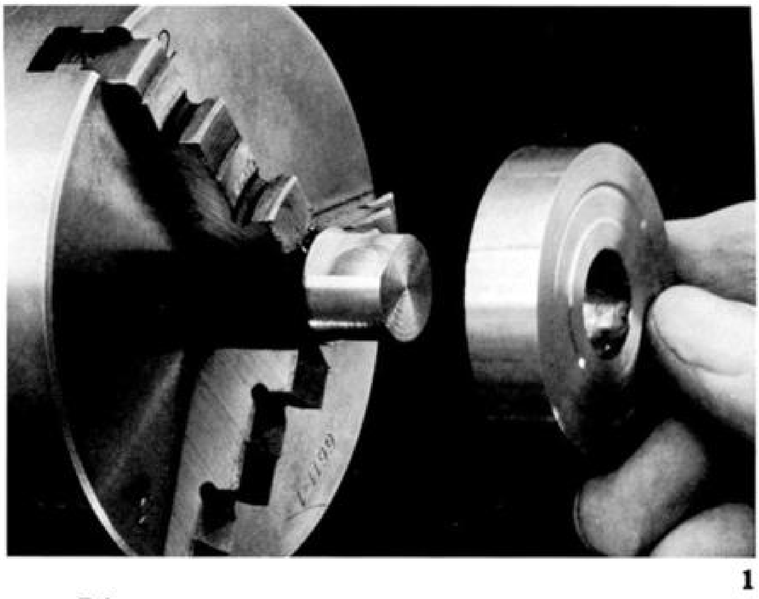
This temporary (discard after use) stub mandrel derives its grip on the workpiece by the wedging action of a pin between a flat on the mandrel and the inner surface of the hole in the workpiece. The stronger the force of the cutting action of the lathe, the tighter the grip becomes. However, if your mandrel is small in diameter in relation to the outside diameter of the workpiece, a heavy machining cut on the work could actually create enough force to flatten the little locking pin and allow it to slip. In cases like this, take light cuts when machining – or use a hardened pin made from drill rod.

To make a stub mandrel, select a piece of round steel rod slightly larger in diameter than the bore of the piece to be worked. Clamp it in the lathe chuck and machine it to a length about equal to the thickness or length of the workpiece (Photo 1). In this case we are making a stub mandrel to fit a roughed-out gear blank.

Carefully machine the diameter of the stub so that the workpiece will *slide* onto it snugly without binding. The next operation is to mill – or file by hand – a flat section on the stub (Photo 2). The depth of this flat is controlled by the diameter of the little locking pin. You should maintain, roughly, a ration of about 12 to 1 between the diameter of the stub and the diameter of the pin.

The pin can be made from a *straight* piece of wire or a portion of a nail, brad, pin or needle, depending on the size you'll need for your particular mandrel. In other words, if the diameter of your stub mandrel is .500", you'll need a pin that's about .040" in diameter. Select the proper size material for your pin and make the length of it about equal to the length of the flat section on the mandrel.

If you file the flat section by hand, try to make the surface as *parallel* to the axis of the mandrel as possible. As you file the flat section, occasionally lay the pin on the flat and mike



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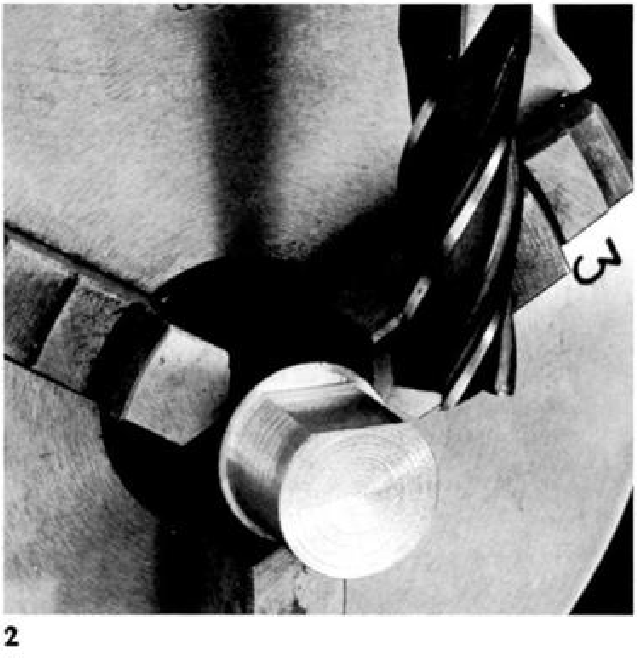

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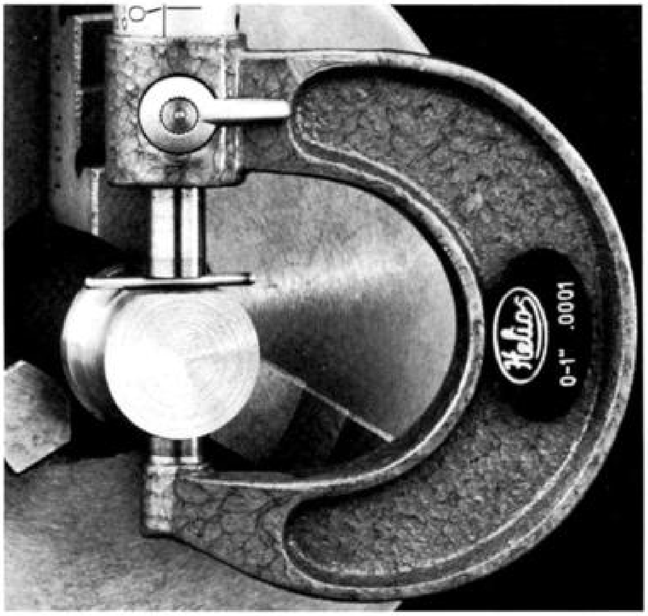

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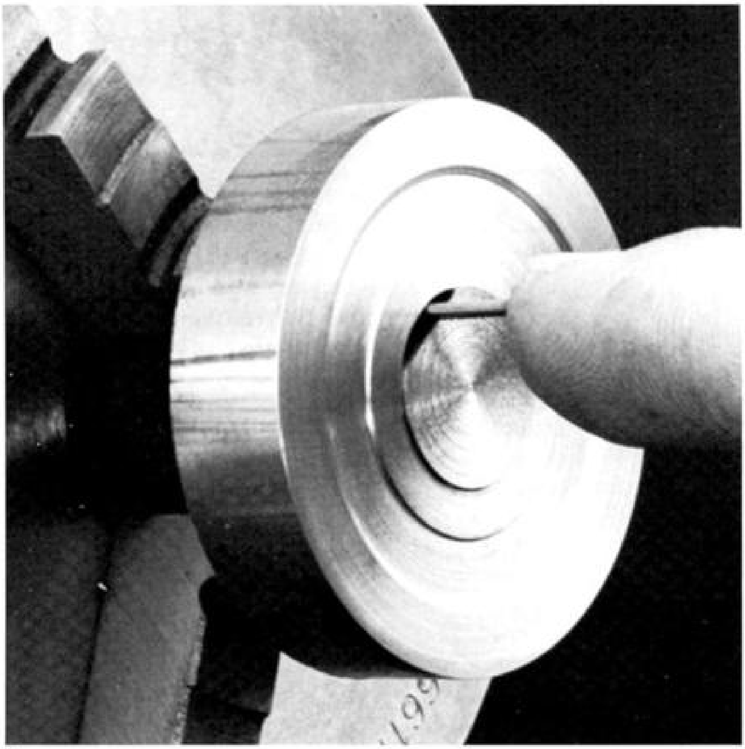
the diameter over the shaft and pin (Photo 3). The flat section is deep enough when the reading is about .002" smaller than the bore of the workpiece. Now slip the workpiece onto the stub mandrel and check to make sure the pin will slide freely into the slot (Photo 4). If it won't, it means your pin is bent or burred on the ends.

When everything fits properly, and you have the workpiece mounted on the stub and the locking pin in place, simply rotate the lathe spindle by hand until the flat section on the stub is roughly in a vertical position *away* from you (towards the back of the lathe). Now hold the lathe spindle to keep it from turning and twist the workpiece clockwise by hand. You'll feel it lock almost immediately. You're now ready to machine the work. When it's time to remove the workpiece, simply twist it by hand in a counterclockwise direction until you feel the locking pin loosen; then slide the workpiece *straight* off.

With the setup you can machine both the outer end of the work and the diameter. If it's necessary to machine the back side of the work, simply remove it and reverse it on the mandrel. By letting the workpiece hang out about 1/16" beyond the shaft, it's easy to machine a chamfer on the sharp edge of the exposed bore hole. If your work calls for a long stub mandrel, it's usually not necessary to mill a flat section the whole length of the shaft (Photo 5). Also, you can center drill the end of the mandrel and support it with the tailstock for more rigidity.



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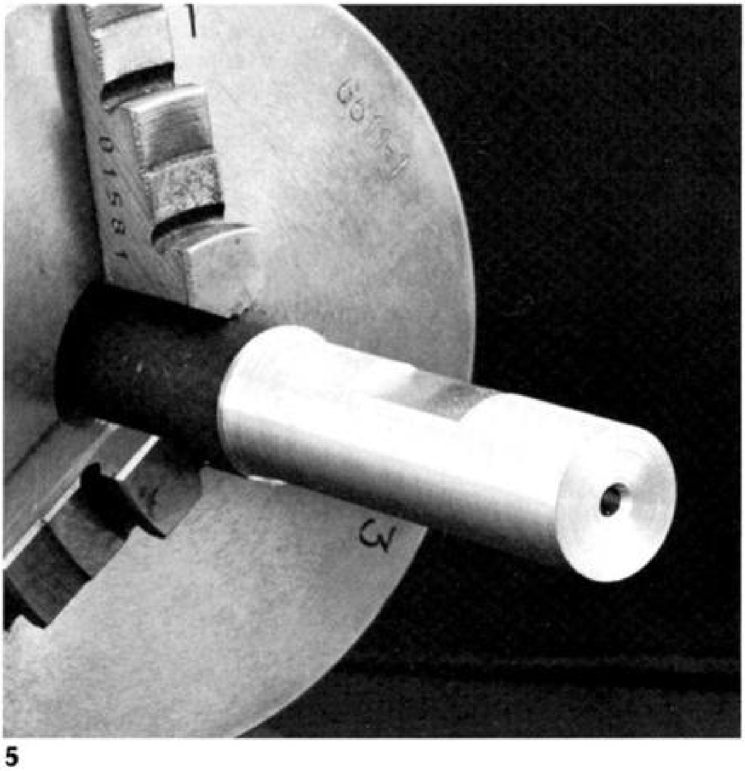

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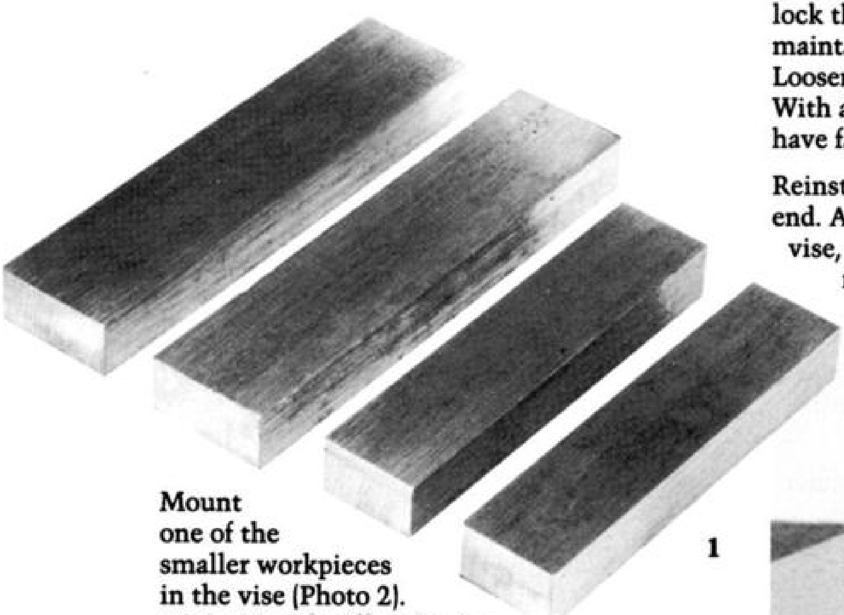
Adjustable Parallels

Do you know it's possible to make your own adjustable parallels merely by using standard size end mills? No special dovetail cutter is needed. Briefly put, an end mill is used to make two *outward angled* cuts that originate from a single groove, thus creating a dovetail.

Photo 1 shows the cold rolled steel bars that were employed to make two sizes of parallels. In theory cast iron is best, but I certainly don't have any cast iron bars lying around. The pair of small bars are 5/16" × 1/2" × 2 1/8" long. The other two are 5/16" × 5/8" × 2 11/16".

Machining time will be improved by working alternately on both parallels. In mounting your angle vise on the mill, it's *very* important to check the accuracy of the solid jaw with a dial indicator. It should be as parallel as possible to the travel of your table. Also, the bed of the vise should be level to the mill table; if it's off, the use of shims under the supporting parallel will be necessary.



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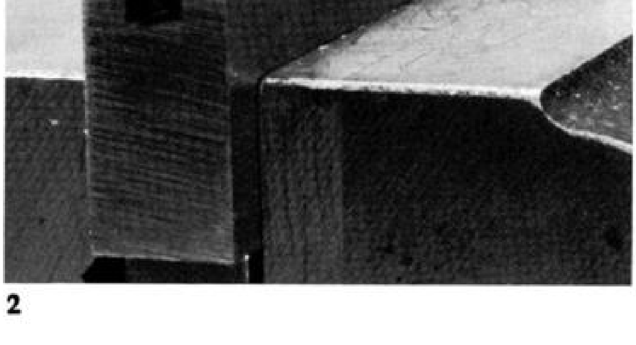
Mount one of the smaller workpieces in the vise (Photo 2). Use a 1/8" end mill and cut a groove 5/32" deep in the *center* of the bar. The method I used to arrive at the center is to position the end mill close to one side of the bar and, with the cutter turning about 1500 rpm, advance it just enough to barely scratch the side of the workpiece. Set the calibrated dial on the mill table to zero. Since our workpiece is about .312" thick, we take half of that *plus* half the diameter of the end mill. That's .156" plus .062", which comes to .218" as the amount necessary to move the cutter over to the center of the work – not perfect, but close enough. Begin milling the groove. Unless you have a drawer full of 1/8" end mills, be very careful; limit each cut to 1/32" in depth. Consequently, you'll have to make five passes through the bar before reaching the required depth. Now remove the bar from the vise, install one of the larger bars and repeat the milling process.

At this point it's *important* that the workpiece be seated *solidly* on the supporting parallel beneath it. I've found that as soon as the vise jaw is tightened, the workpiece will rise slightly. Use a *lead* hammer and pound it down until it is positioned *snugly* and *evenly* on the support. Unless you have a tilting head on your mill, it's now time to tilt the angle vise up 5° as in Photo 3. Take a light cut – just enough to resurface the top side next to the groove *nearest* the solid jaw of the vise. Now lock the height adjustment of your spindle to maintain the vertical position of the cutter. Loosen the vise jaw and remove the workpiece. With a brush, *carefully* remove any chips that have fallen on the support parallel in the vise.

Reinstall the workpiece, *reversing* it end for end. Again, and *every* time it's reversed in the vise, seat it solidly with a *lead* hammer. Now mill the other top surface. Next, lower



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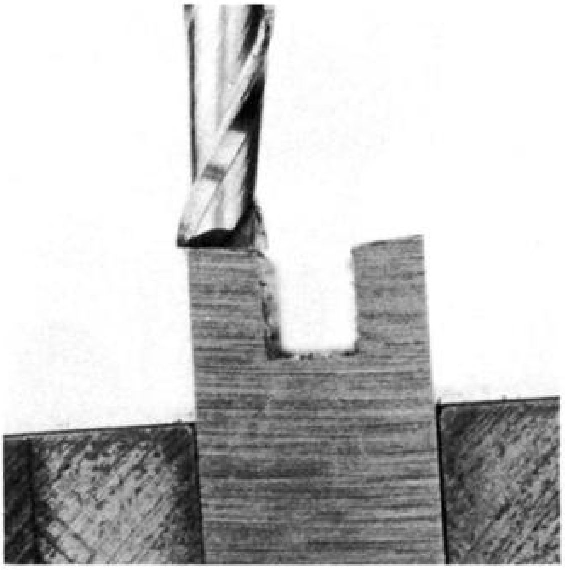
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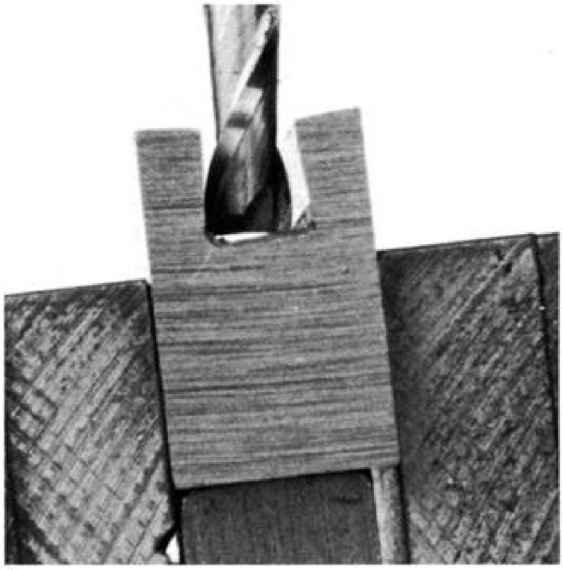
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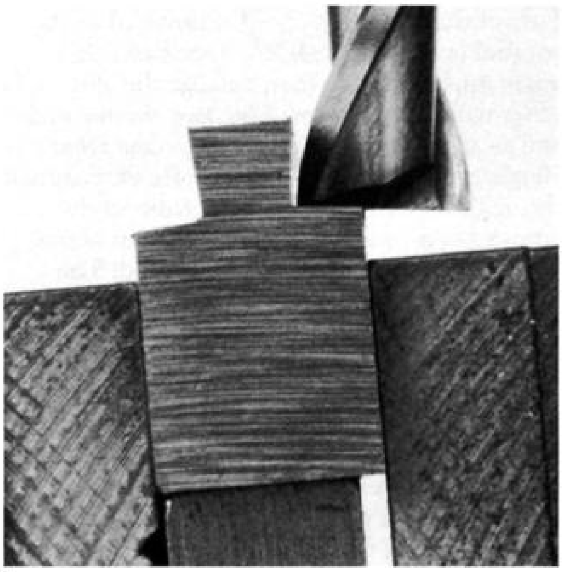
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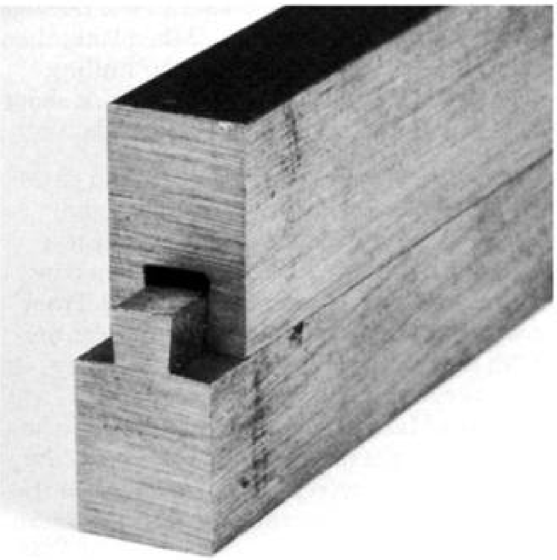
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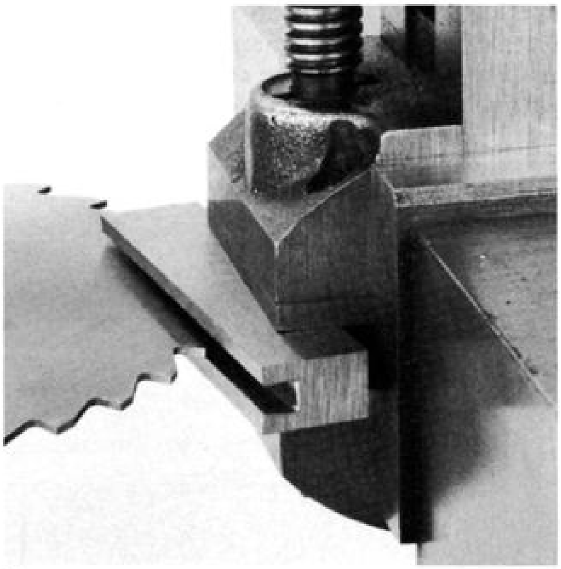
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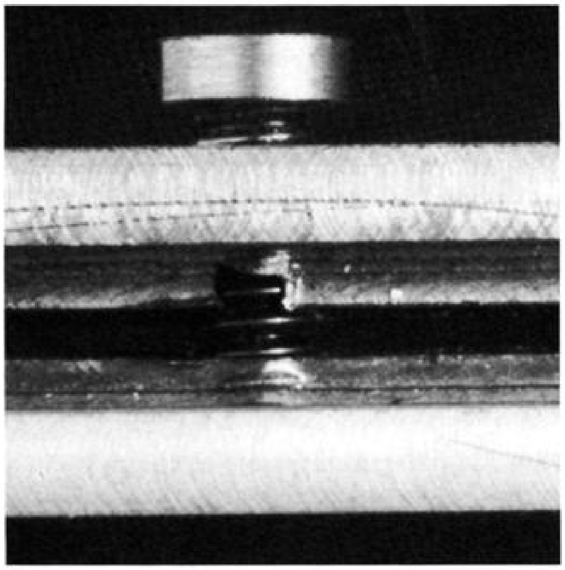
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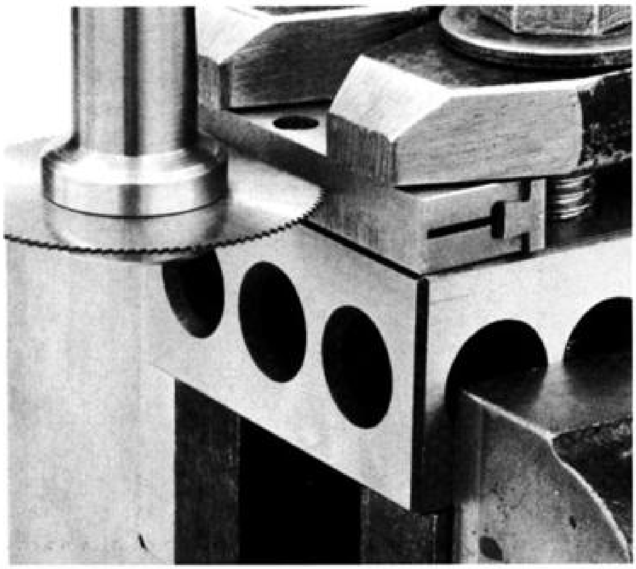
the end mill (be sure it's a sharp one) and proceed to mill the *side* of the groove nearest the solid jaw of the vise (Photo 4). Mill just enough to resurface the side up to the top edge. Run the cutter back and forth until it stops cutting. Lock the mill table so that the end mill maintains its position. Now remove the workpiece and reverse it end for end; make certain there are no chips underneath it. Mill the other side of the groove, and again run the end mill back and forth until it stops cutting.

Now install the other grooved bar for your second parallel. Repeat the whole process, beginning with Photo 3. When you've finished set these two pieces aside, and install one of the other blank pieces in the vise just as you did the first. When you mill the male dovetail (Photo 5), use a ¼" or ⅜" diameter end mill (more rigidity), but be sure to see that the outer end of the cutter clears the vise. Lower the end mill ⅛" from the top surface of the blank, then lock the height adjustment of your milling machine. Move the cutter into the work about .050" and machine a step along one side.

At this point, don't change the position of the end mill. Now remove the workpiece and reverse it end for end; be careful to reseat it properly in the vise. Mill that side. You now have a roughed-out, oversized dovetail. From now on it's a matter of whittling away at the width of the dovetail until it mates snugly with its counterpart. You can get a rough estimate of how much more material is to be removed by measuring with a rule across the width of the grooved piece down 1/16" from the outer edge and comparing that with the width of the tongue up 1/16" from the bottom of the step you are working on. Remember, every time you remove .001" from one side, you'll also have to remove .001" from the other side by reversing the workpiece in the vise.

While all of this is going on, bear in mind that you can take metal *off*, but you *can't* put it back on. After each cut check to see if the mating part will fit. When it will almost go on, it's time to reduce the cut to perhaps .0005". Face one side and again check for fit. If it still refuses to slide on, then reverse the workpiece again and machine the other side. The ideal fit is one that slides fairly easily but with little or no side play or wobble. Photo 6 illustrates how your parallel will appear at this point.

Photo 7 is the next step, that of milling a slot in the parallel. A cut is made in the grooved section along the entire length of the parallel at a point slightly above what will become the *base* of the parallel. Since the dovetail of the parallel is at an angle to the true base, this angle must be used when cutting the slot – in other words, the slot will be deep on one end and so shallow on the other as to disappear. Height and length of the workpiece determines the angle. Measure from the bottom of the *groove* at one end and down to a point about 1/32" *above* the corner at the other end. The angle to use for our short parallel is 8° and for the long, 6°. Clamp the small parallel, groove side out, at an angle of 8° in a vise. Then position the vise in a larger vise as illustrated. Two alternative holding methods would be to clamp the vise to an angle plate – or, as visible in Photo 9, merely hold the workpiece to a 1-2-3 block in a vise. Use a 1/32" slitting saw to cut a slot along the center line of the dovetail.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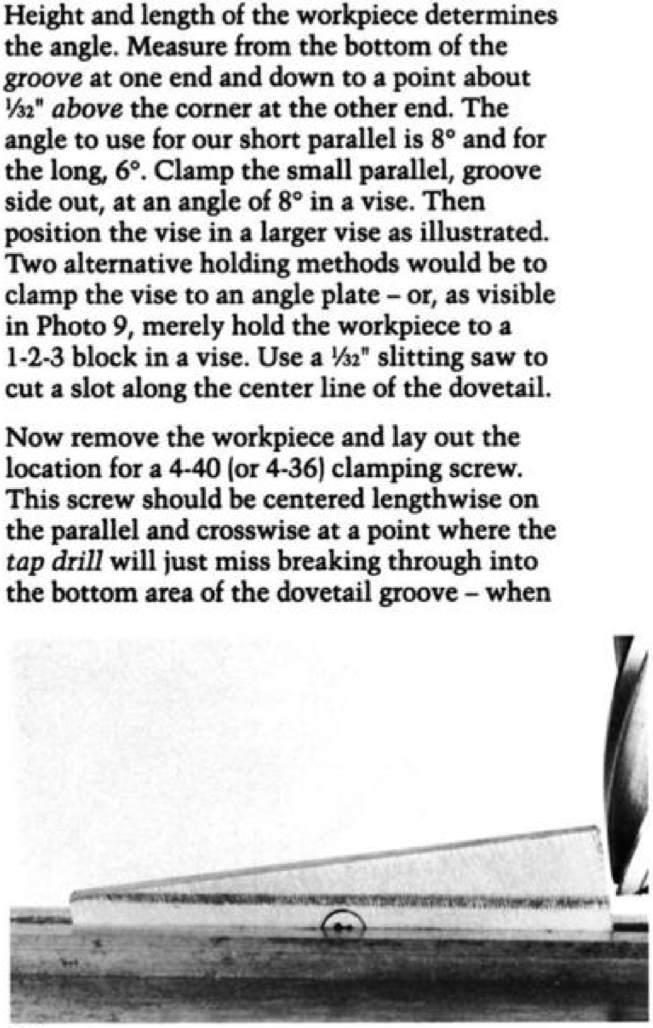
Now remove the workpiece and lay out the location for a 4-40 (or 4-36) clamping screw. This screw should be centered lengthwise on the parallel and crosswise at a point where the *tap drill* will just miss breaking through into the bottom area of the dovetail groove – when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threaded, it probably will break through. Photo 8 is a view looking into the dovetail of the parallel. The tap hole through the lower half of the parallel has been threaded and the hole through the upper section enlarged to allow the screw to slip through; this hole has been counterbored to accommodate the screw head. I used a Phillips-type filister head screw but found it necessary to shorten the depth of the head to 1/16" – it wouldn't have been wise to counterbore the head into the parallel any deeper than that.

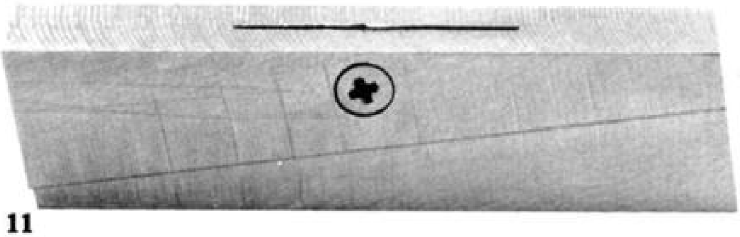
Since there's only one screw in the small parallel, it's necessary to cut a 1" long slit on the parallel behind the bolt hole (Photo 9). This allows the screw to exert more clamping pressure on the mating part. On larger parallels this slit is eliminated and *two* clamping screws are used.

Now, with the parallel assembled and the clamping screw tightened, place the parallel in your mill vise; support it on parallels so that its *flat* surface is slightly exposed above the vise jaws. Use a large end mill or fly cutter and take a light cut – just enough to clear up that side. Do the same with the other side.

Now mount the work edgewise in the vise at an angle of 8° (Photo 10). The area above the dark line must be removed, but not all in one swipe as the photo might indicate. Take light cuts until evidence of the 8° angle is gone. Then remove the workpiece and eliminate any burrs that may be present. Return the parallel to the vise; support the *edge* you've *just machined* on an *accurate* parallel. Repeat the machining process as indicated by Photo 10. At this point your workpiece should resemble the one in Photo 11. Again clamp it in the vise, this time in a vertical position, and square off each end.

Well, that's it – you're finished. Of course, if you have access to a surface grinder you can pretty-up the parallels as in Photos 12 and 13.

This method of making dovetails has other applications, too. As an example Photo 14 illustrates the use of this principle in building my homemade boring head.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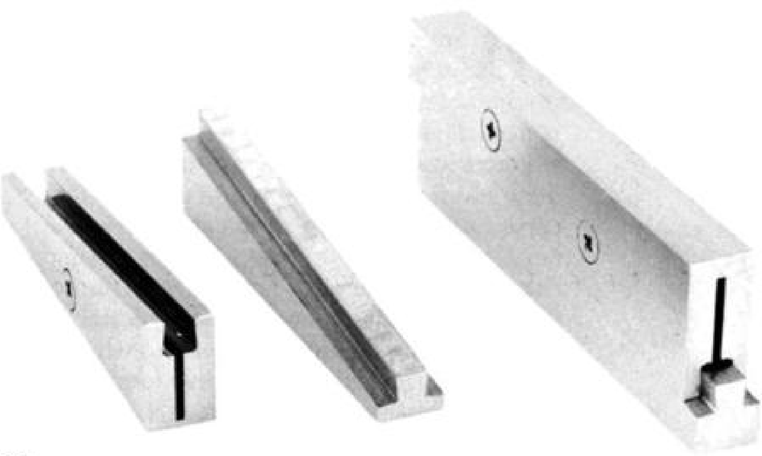
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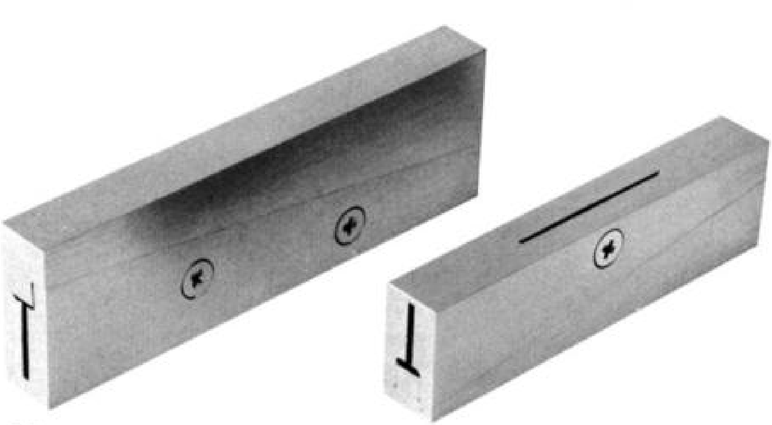
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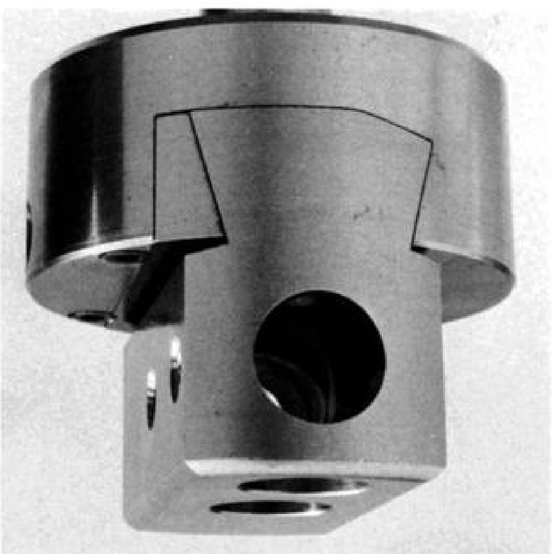
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A Temporary Aluminum Furnace

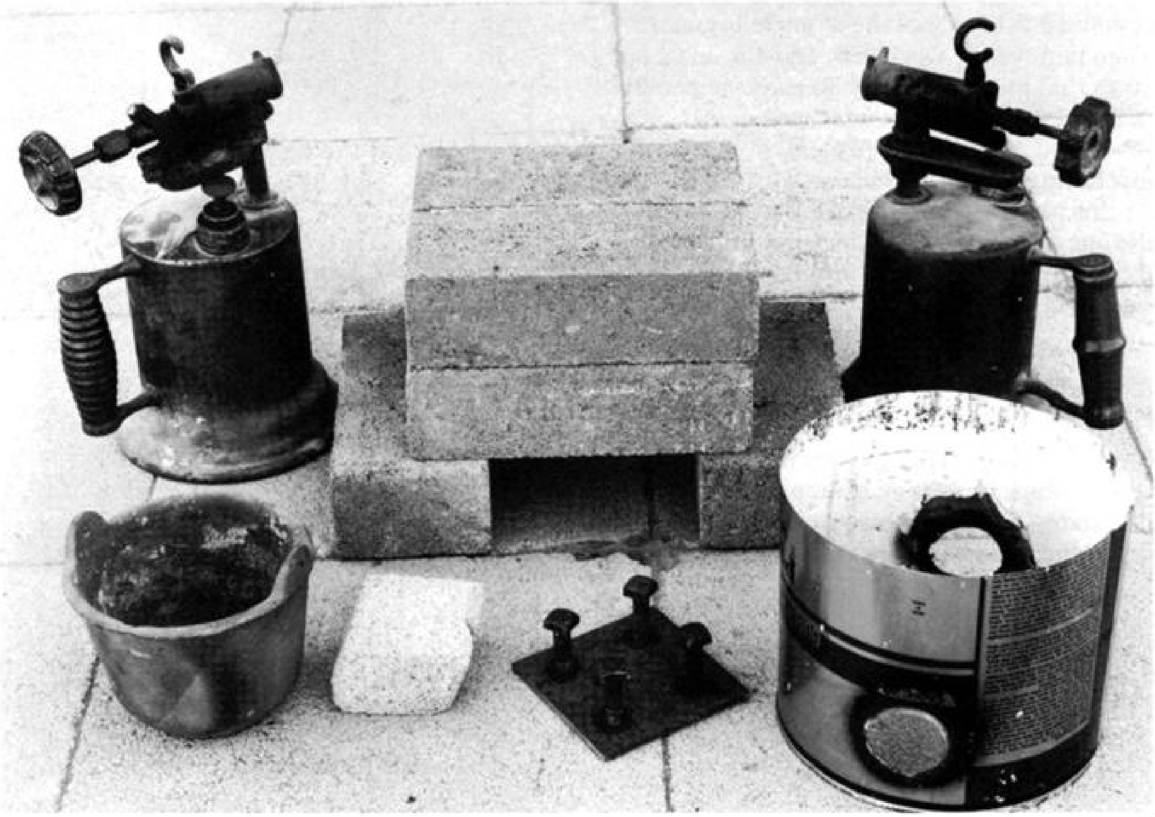
Many home workshop enthusiasts have probably longed for an easy, inexpensive method of melting aluminum or zinc. All that is needed are six dry bricks (either clay or concrete), two old-fashioned plumber's gasoline blow torches, a small cast iron pot (one pint capacity), an old one-gallon paint can and a small piece of clay brick as a footing to support the cast iron crucible (Photos 1 & 2). Photo 3 illustrates the use of an optional pedestal made from a square, flat piece of steel into which four ⅜" by 1¼" bolts are screwed, thus forming the pedestal. This pedestal is more efficient than the brick one because it allows heat to circulate freely beneath the crucible.

The height of the blowtorches should be adjusted so that the flames are hitting the lower portion of the crucible near its base and at a slight angle so that the flames tend to swirl around the pot.

Cut out the bottom of the paint can with a can opener, and then cut two round holes on opposite sides to allow the torch flames to hit the crucible. Cut down the height of the can so that it's about ½" taller than the crucible (Photo 4).

Don't use regular gasoline in this type of torch; use "white" gasoline or *Coleman*-type fuel used for camp stoves and lanterns. If you don't have torches of this type, you may possibly find them at a swap meet or be able to order them from your local hardware store.

The furnace can be set up outdoors and operated on a *windless* day, or in an open sheltered area. Be sure to fill the crucible with small pieces of scrap aluminum before igniting the torches. After the heat is applied and the aluminum *begins* to melt and settle in the pot, keep adding more aluminum so that the pot is always loaded to the top with unmelted pieces. If your furnace is operating properly, it will take roughly 35 minutes to melt a pot full of aluminum.



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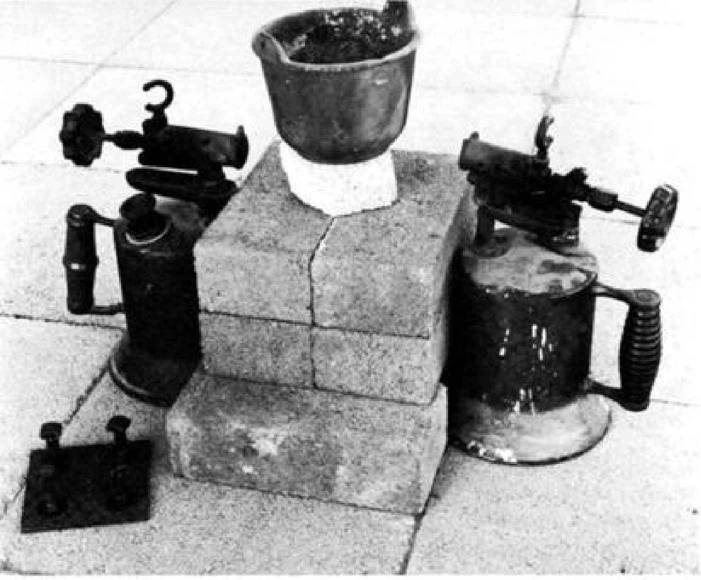

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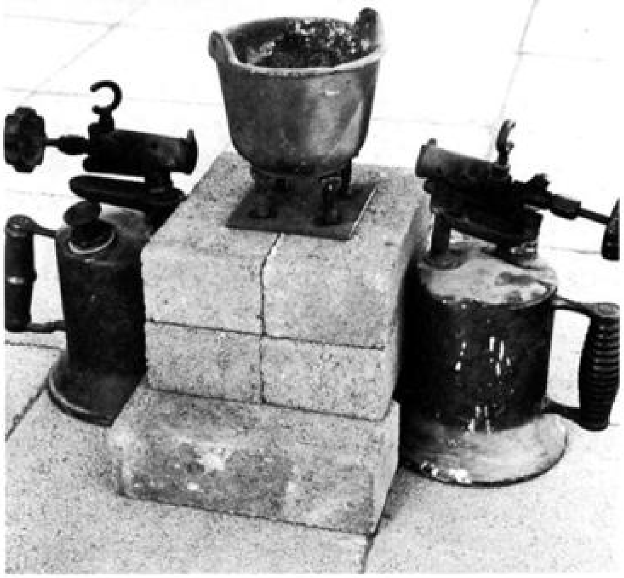

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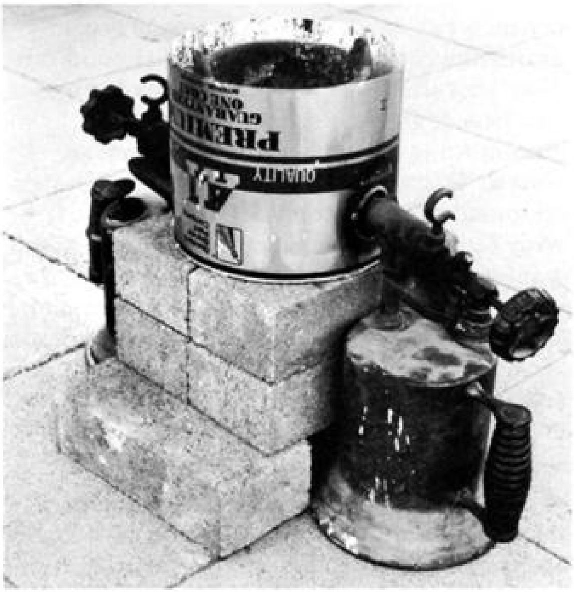

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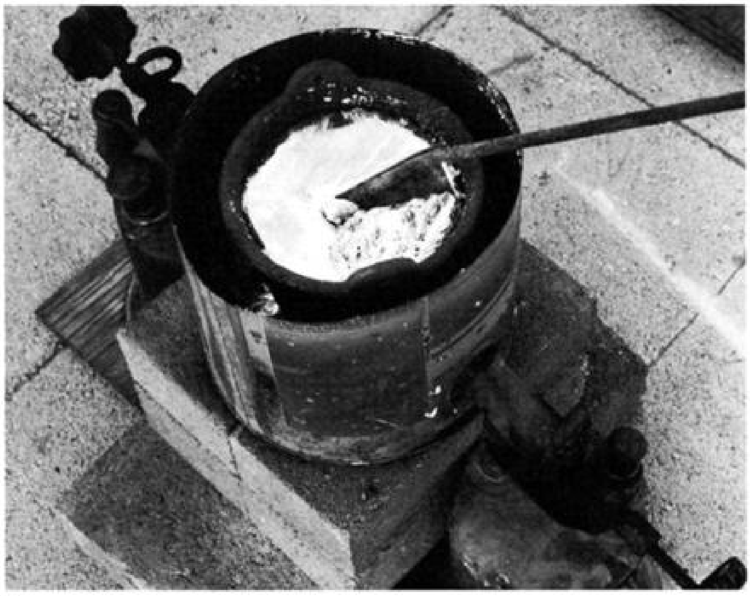

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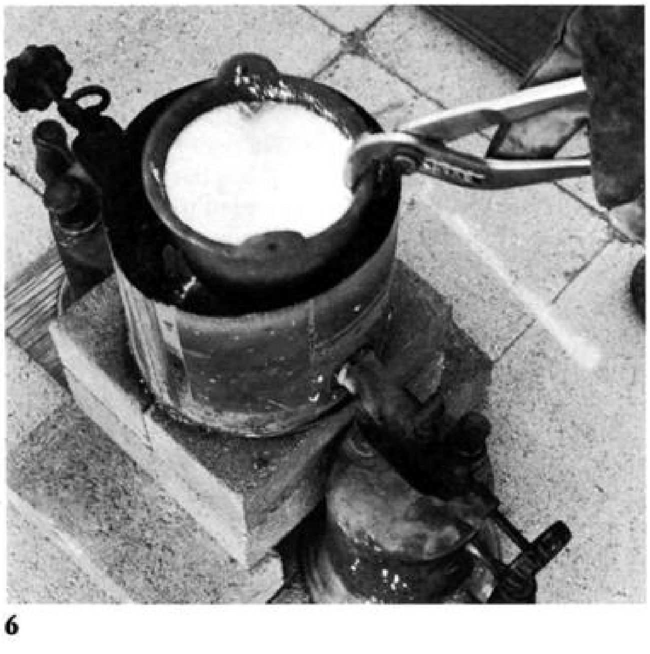
Allow the heat to continue for three or four minutes longer to build up to a proper pouring temperature; stir and then skim off any sludge floating on the surface (Photo 5). When ready to pour you can safely lift up the pot with a long-handled offset pair of pliers – use thick leather gloves (Photo 6). I've made many hundreds of castings using cast iron pots, gripped them with pliers and had no accidents. However, if you use a clay or graphite crucible do *not* attempt to lift them with pliers – such crucibles are quite delicate and might break. Always use a crucible tong made especially for your particular size crucible.

For those of you who have not experienced the thrill of pouring your first sand casting, I suggest you read up on the process of sand mold making. There are many excellent booklets available, and a very good source for them is *Lindsay Publications*, P.O. Box 12-PA, Bradley, IL 60915-0012.



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Degassing Molten Aluminum

Considerable information is available about the methods of melting aluminum. Surprisingly, some of the "do's and don'ts" contained in one book contradict statements made in another. For instance, one "expert" will inform you *not* to use old aluminum automobile pistons as a source of material. Another will say that aluminum pistons are just fine.

I'm inclined to agree with the latter. Let's face it. Most of us will be making aluminum castings under considerably less than ideal conditions. I use just about any type of scrap cast aluminum I can get my hands on. Perhaps 90% of these castings will be satisfactory; yes, the majority will be pockmarked with minute imperfections – imperfections visible only on machined surfaces.

These defects can be greatly reduced by degassing the molten aluminum. Unfortunately, there seems to be very little printed information available on the actual degassing process. As an example, one supplier of the degasser chemical merely advises: "Plunge (the degasser chemical) to the bottom of melt with hook or plunger." This dealer will sell, for about $50, no less than 10 lbs. of the degasser – enough chemical to process *4,000* lbs. of aluminum!

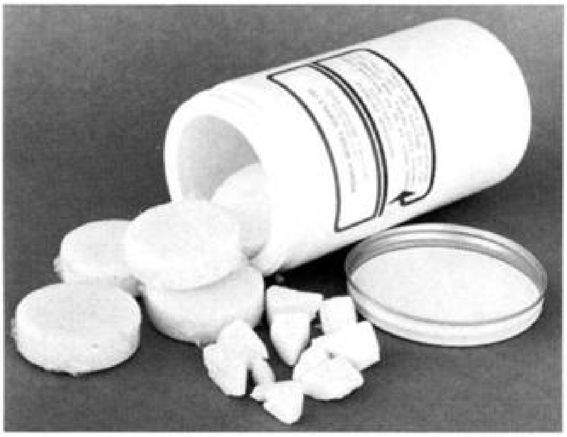
Fortunately for us, Power Model Supply Company, Rt. 1, Box 177, N.W. Cor. Hwy.67 and Long Road, De Soto, MO 63020, offers a package of twelve 2-oz. pellets of degasser for about $6 – that's enough to treat *1,200* lbs. of aluminum (Photo 1). Each pellet is sealed in a plastic envelope for protection against the harmful effects of air and moisture. One 2-oz. pellet will treat 100 lbs. of aluminum; therefore, if you intend to melt only a few pounds of metal, it's necessary to cut a pellet into small pieces. A little-too-much chemical is preferable to not enough. The enlarged Photos, 2, 3, and 4, clearly illustrate the advantages of using a degasser.

Photo 2 is an example of a machined casting in its most wretched state, a prime display of overheated, untreated aluminum. Photo 3 shows an untreated casting, complete with a fair amount of pitting and a mottled appearance. Photo 4 reveals the marked improvements obtained with the degassing process.

A homemade plunger (Photo 5) can be machined from a round piece of steel (cast iron would be preferable) about 1-1/2" in diameter by 5/8" in length. For a handle, I used a piece of 1/4" x 2 feet steel threaded to the back of the cup. A series of 1/4" holes around the cup perimeter allows the gases to escape properly during the degassing process, I must point out now what the "experts" claim – any form of cast iron or steel in contact with molten aluminum is a "no-no"! In theory they are correct. To improve the quality of the castings, all metal tools and crucibles should be coated with *Terrapaint* (a liquid ceramic paint). If you want your castings to be the very best, follow the expert's advice. However, since degassing alone renders such a marked improvement in aluminum castings, it would appear that the added bother of continually "Terrapainting" everything outweighs its advantages.

To degas small amounts of aluminum (3 or 4 lbs.), it's best to bring the metal up to its proper pouring temperature and then lower the furnace flame to prevent overheating the metal. Immediately skim off most of the floating scum and place a piece of the degasser chemical on top of the melt (Photo 6). Promptly cover it with the plunger and push it to the bottom of the crucible. A certain amount of light-colored smoke will be emitted, so make certain your foundry area is well ventilated. You'll notice many large bubbles rising to the surface of the aluminum (Photo 7).

Since the degassing chemical does *not* mix with the aluminum, the cleansing process is purely mechanical. The rising bubbles do all the work by absorbing some of the offending gases in the metal. Therefore, move the plunger around the *bottom* of the crucible and allow the bubbles to do a good job. Usually, in one or two minutes the bubbling will cease – a signal the chemical has been consumed. Remove the plunger. You'll find that an amazing amount of new dross has risen to the surface of the metal. Skim it off – then pour your casting! You'll be pleased with the results.



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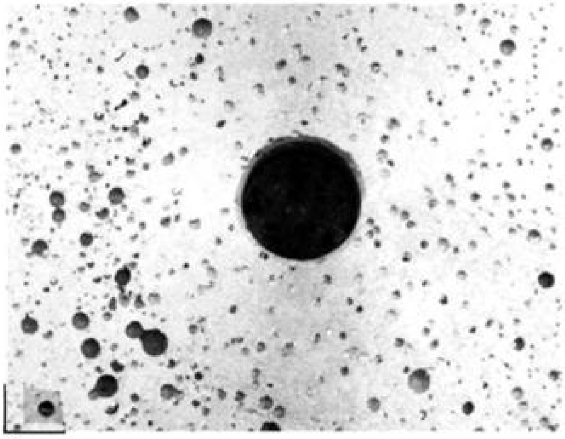

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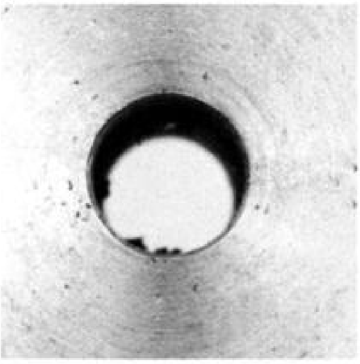

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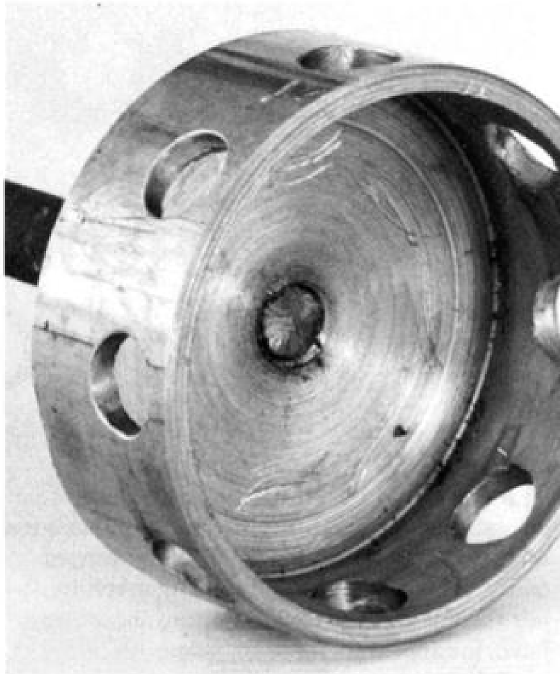

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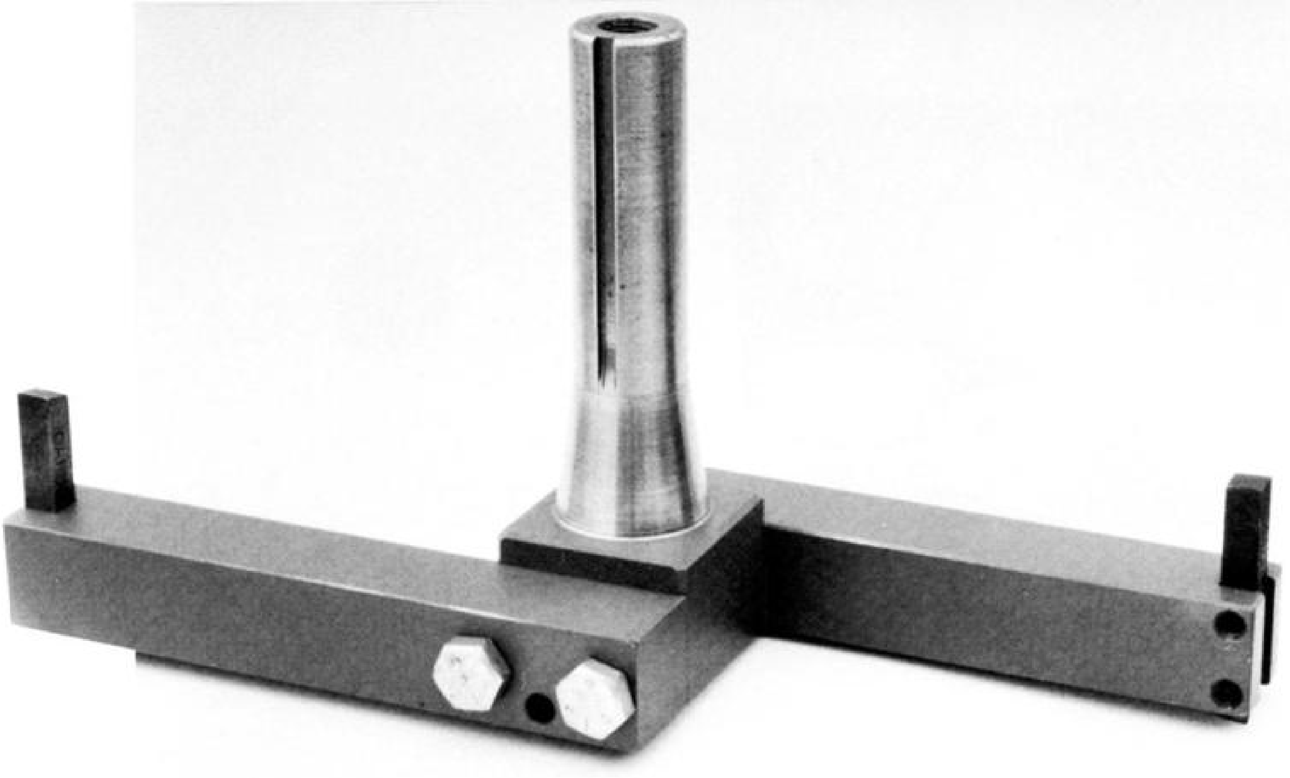

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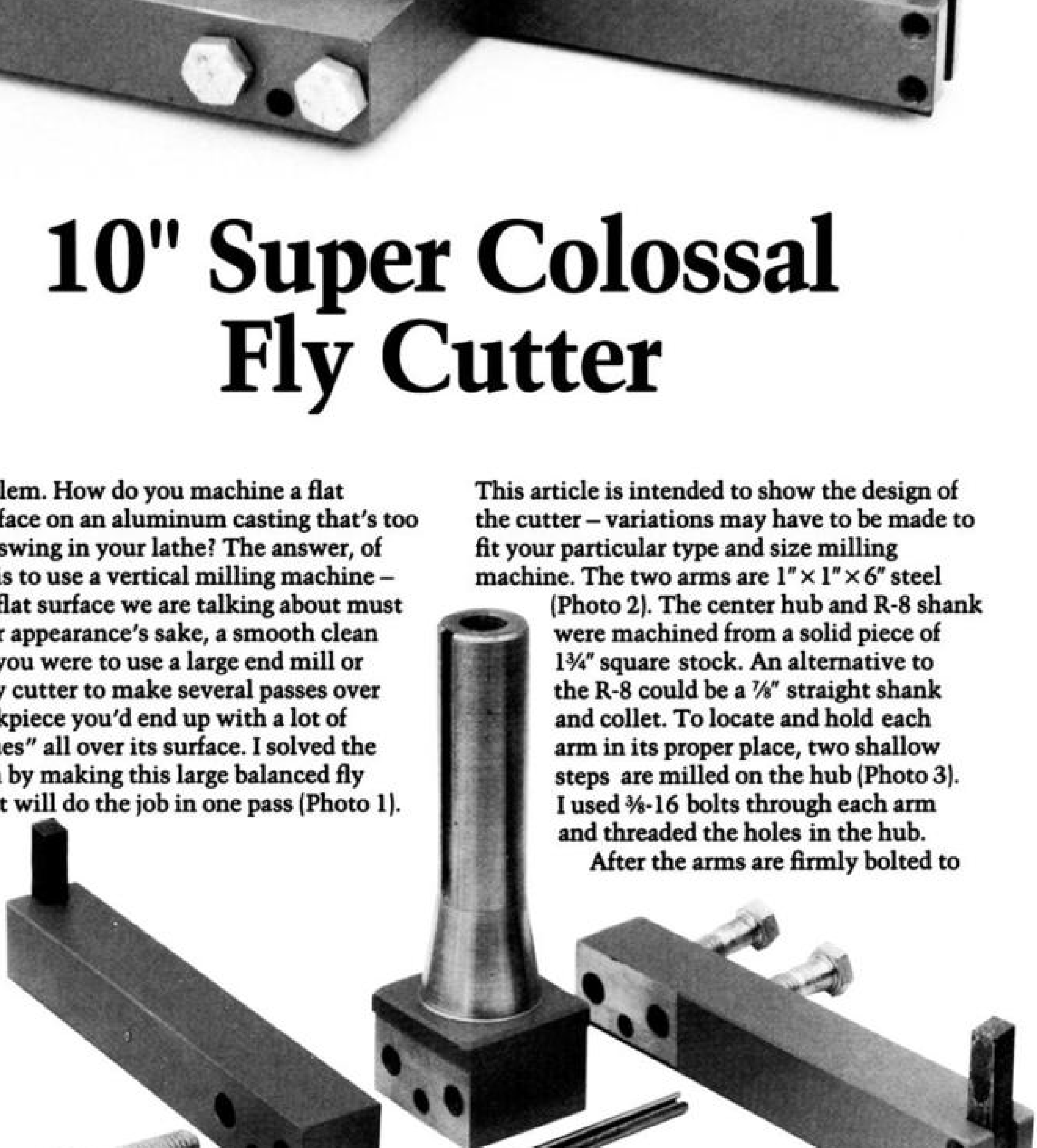
10" Super Colossal Fly Cutter

Problem. How do you machine a flat surface on an aluminum casting that's too large to swing in your lathe? The answer, of course, is to use a vertical milling machine – but the flat surface we are talking about must have, for appearance's sake, a smooth clean look. If you were to use a large end mill or small fly cutter to make several passes over the workpiece you'd end up with a lot of "curlicues" all over its surface. I solved the problem by making this large balanced fly cutter; it will do the job in one pass (Photo 1).

This article is intended to show the design of the cutter – variations may have to be made to fit your particular type and size milling machine. The two arms are 1″ × 1″ × 6″ steel (Photo 2). The center hub and R-8 shank were machined from a solid piece of 1¾″ square stock. An alternative to the R-8 could be a ⅞″ straight shank and collet. To locate and hold each arm in its proper place, two shallow steps are milled on the hub (Photo 3). I used ⅜-16 bolts through each arm and threaded the holes in the hub.

After the arms are firmly bolted to



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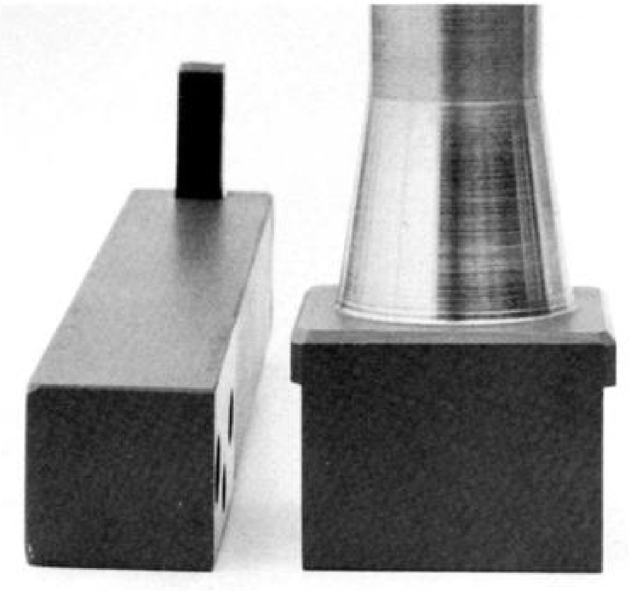

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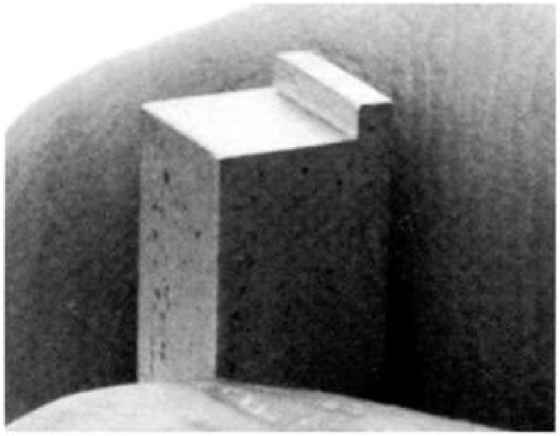
the hub, a third hole, ¼" in diameter, was drilled through both arms and hub; a long ¼" spring dowel was then driven in, thus assuring that nothing would shift under stress.

By accurately drilling one or two more properly spaced bolt holes in each arm, it would be possible to adjust the cutter's range to a smaller diameter.

My fly cutter utilizes two ordinary 5⁄16" carbide-tipped lathe tool bits; it's necessary to locate them fairly accurately in relation to each other, otherwise only one tool will be doing most of the cutting. A simple locating jig is made by milling a 3⁄64" deep step on the end of a short length of ¼" square steel (Photo 4). Mount this vertically in the mill vise and, with the fly cutter attached to the spindle of the milling machine, swing a cutter arm around to locate the loosened tool bit so it will touch both the horizontal and vertical portions of the step in the locator (Photo 5). Then tighten the setscrews to hold the tool bit in position. Unfortunately, this tightening process may cause the bit to press downward somewhat on the locator; the bit may dig in when you attempt to move the fly cutter arm. So just grasp the end of the arm firmly, press *upwards* and thus swing the tool off the locator. Follow the above procedure on the second cutter arm. Although this method is not *perfectly* accurate, it's close enough for our purposes.



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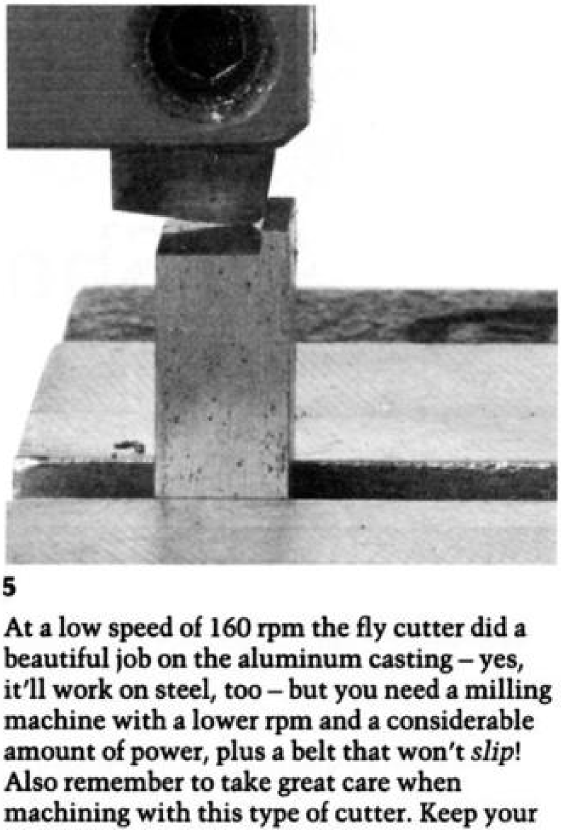

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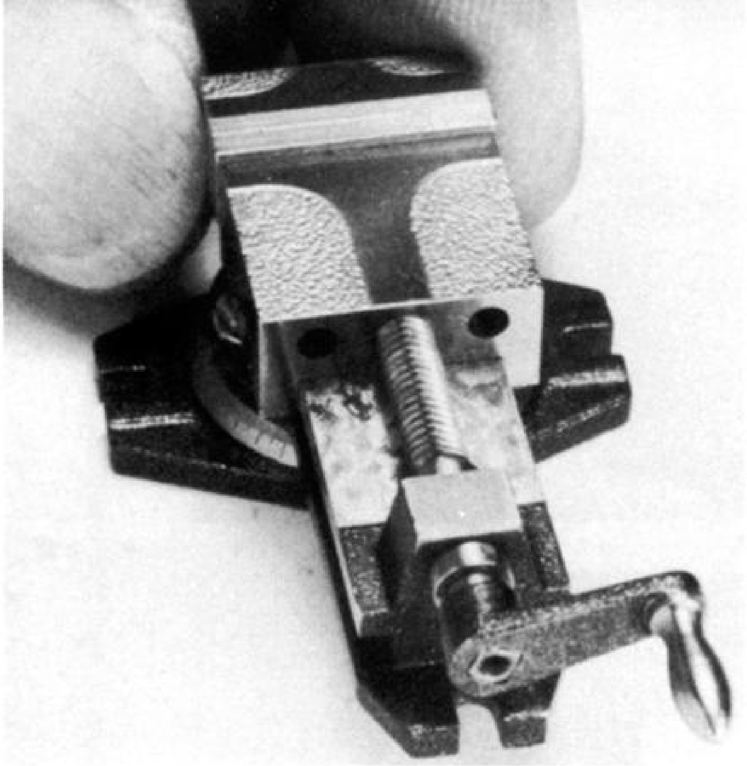
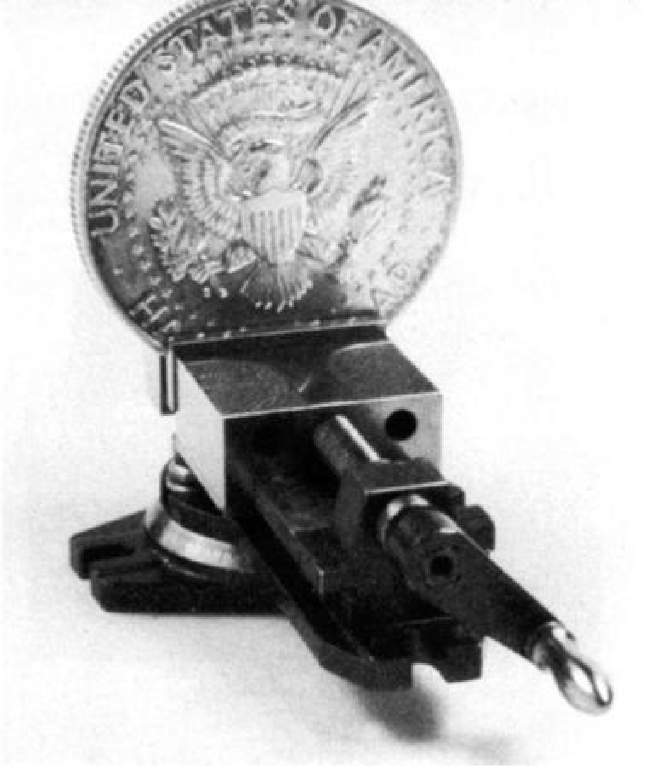
At a low speed of 160 rpm the fly cutter did a beautiful job on the aluminum casting – yes, it'll work on steel, too – but you need a milling machine with a lower rpm and a considerable amount of power, plus a belt that won't *slip*! Also remember to take great care when machining with this type of cutter. Keep your nose and fingers out of the way, unless you like mincemeat! Always wear protective goggles as hot chips really do fly.





A "Showpiece" Challenge

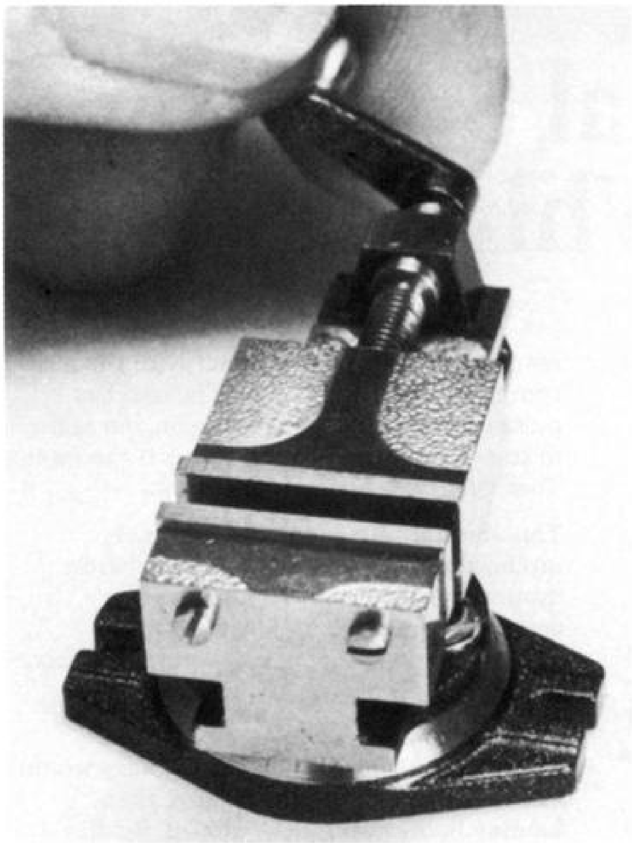
Recently I finished a rather dull project; you know the type – where it's necessary to make a tool to make a tool to make a tool. After cleaning up the mess in the workshop, a thought came to mind: why not build something that would be cute, a challenge, fun to make and absolutely *useless!* My eyes fell upon a 5" swivel-base milling machine vise. Why not try to make a tiny miniature of it?

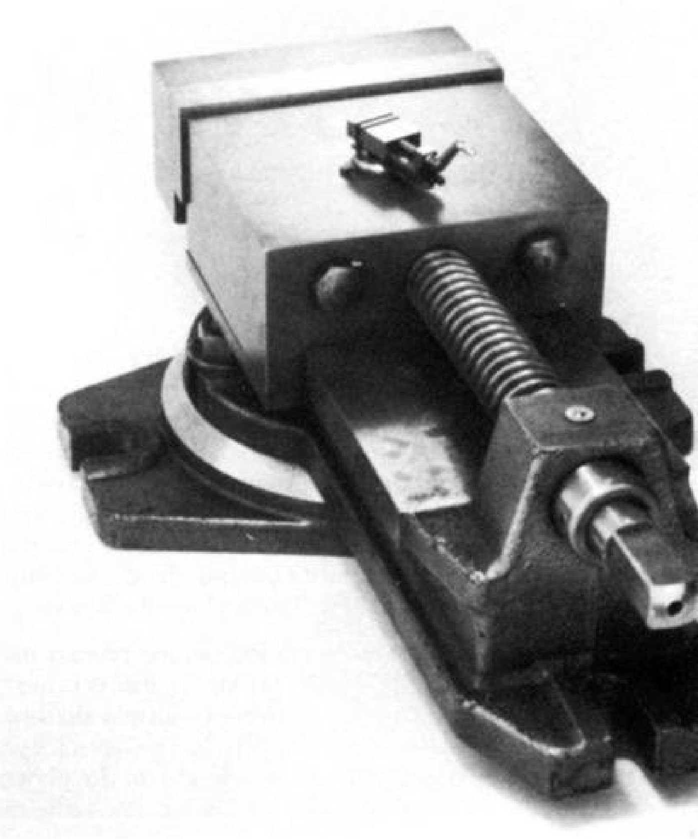
I settled on making the little vise about ⅛ the size of the large one. To further enhance the challenge, I decided that no sketches or plans would be allowed. All parts were to be machined from solid pieces. No press fitting or silver soldering parts together, including the little hand crank. No filing allowed – all parts to be machine-finished in a lathe, mill, drill press or surface grinder. The tiny left-hand screw that activates the movable jaw would be machined in the lathe. Also, the movable jaw would not be allowed to show any detectable play either up and down or sideways. A broach would have to be fabricated to form the square hole in the crank.

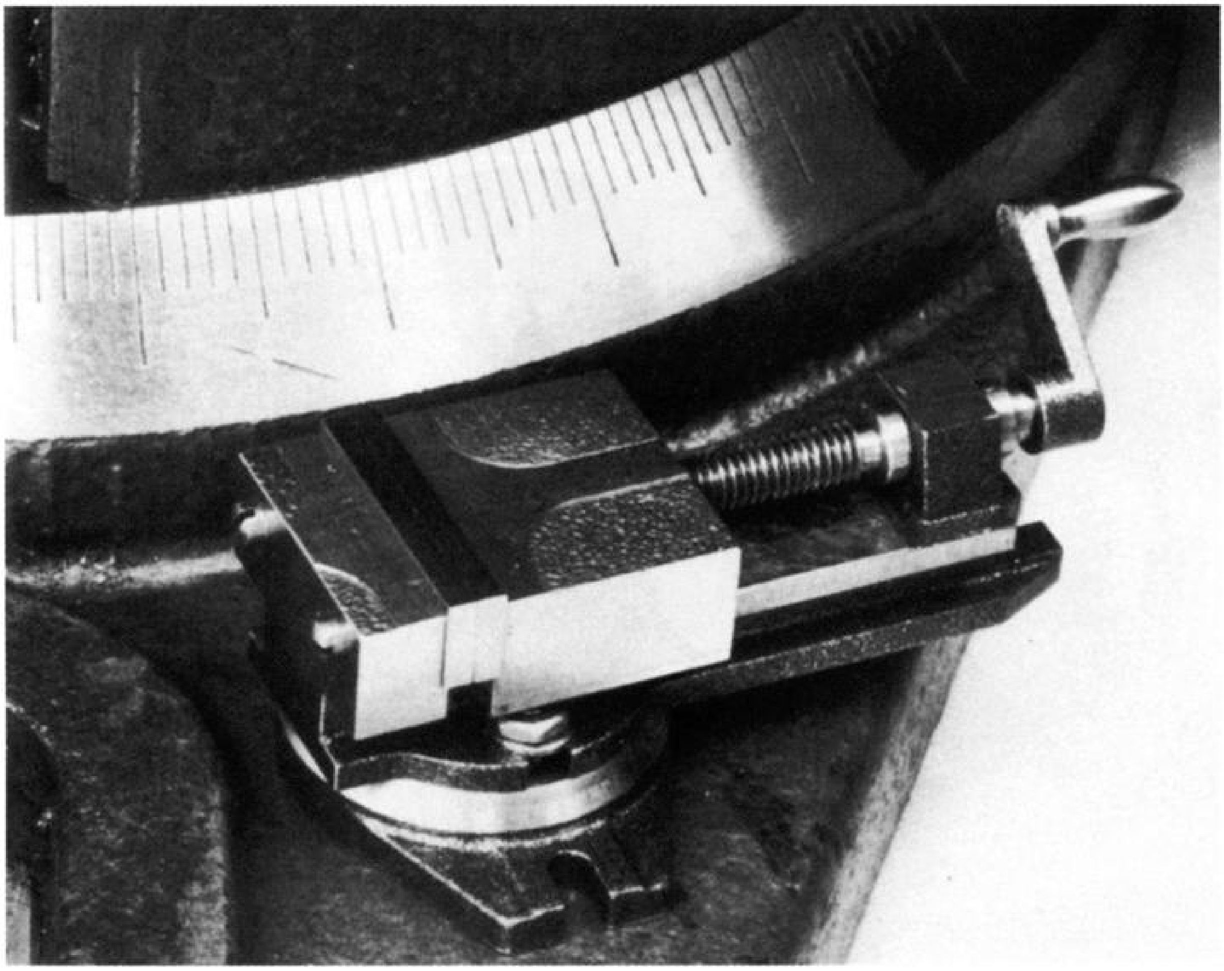
A wrench, a screwdriver, small hand taps, some fine emery paper, a tiny hand scraper and a small ball-point center punch (both used for decorative purposes) would be the only hand tools I would use. Portions of the vise can be painted – that would cover up a multitude of sins!

I can't remember when I've enjoyed building anything as much. And instead of the responses from people being an unenthusiastic "Uh-huh, that's nice," they usually went, "What *is* it? How long did it take you to make it? How pretty. That's certainly cute; if it wasn't so heavy I'd like to hang it around my neck." In other words, my little whatszit is not only a showpiece, it's also a conversation piece.

By the way, I didn't scribe any degree numbers on the little vise base, because the big vise I copied it from doesn't have any numbers on it either (see the last photo). Like father like son. Just a chip off the old block! (I am proud to say that the little degree lines are separated by only about .006".) And just think – I'm the only one in the whole world who has one of these thingamajigs. Well…for the moment, anyway.







Give Metal Spinning a Whirl!

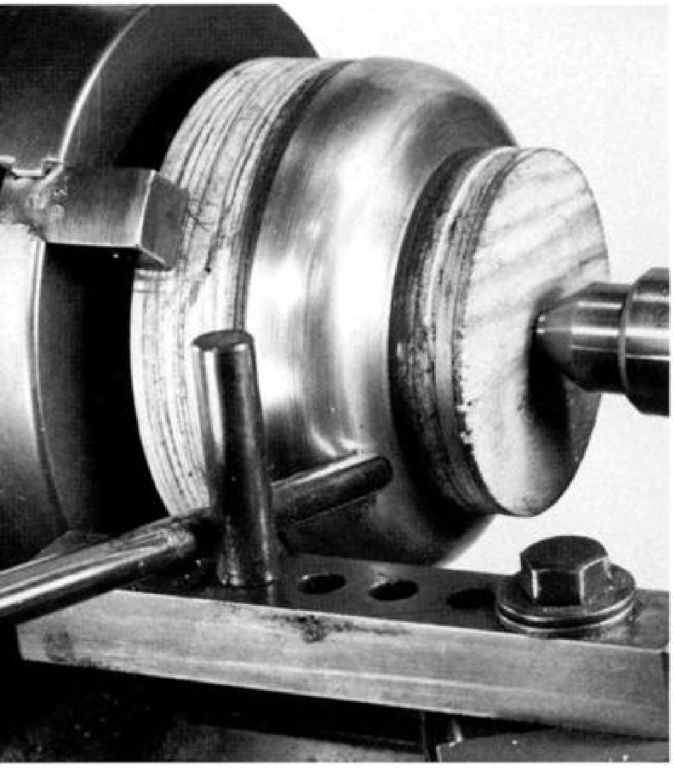
Metal "spinning" with a lathe is a process that gradually transforms a revolving disc of sheet metal into a variety of shapes – perhaps a vase, a bowl, or a lamp base. It is regrettable that many of us who have the facilities to practice this ancient craft have completely ignored it – for there are times when the ability to spin metal would be invaluable to a home shop machinist.

Let's take a quick look at the process involved. In Photo 1, a soft aluminum disc is being "spun" over a wooden pattern to form a shallow bowl. The workpiece is held in firm contact with the pattern by pressure exerted on the plywood disc by the tailstock center. The lathe carriage has been locked in place and its tool post replaced with a husky steel bar equipped with holes in which an upright steel stud is inserted. This provides a fulcrum point on which the tool can exert pressure upon the workpiece. A portion of the tool, which is about two feet long and held by the operator, is visible braced against the stud and in contact with the nearly completed aluminum bowl. The tool has passed over the rotating disc again and again to smoothly press the metal against the form. That, briefly, is how a disc is spun.

This short article on metal spinning is intended for the beginner. Only the barest minimum of tools and fixtures will be described, thus making it easier for the uninitiated to get started on a simple project.

Entire books have been written on the subject of metal spinning, so if you need more information, perhaps your local library would have a book on the subject. If not, then Lindsay Publications, P.O. Box 12, Bradley, IL 60915-0012, sells a nice little book on metal spinning. Write for their free catalog.

Be forewarned – for the beginner, there is nothing "cut and dried" or foolproof in being 100% successful in the first few attempts at metal spinning. It takes a certain amount of



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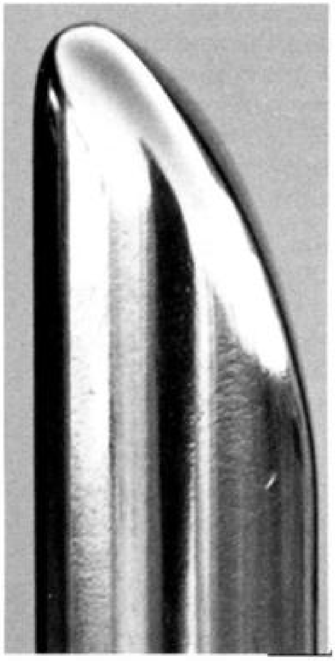

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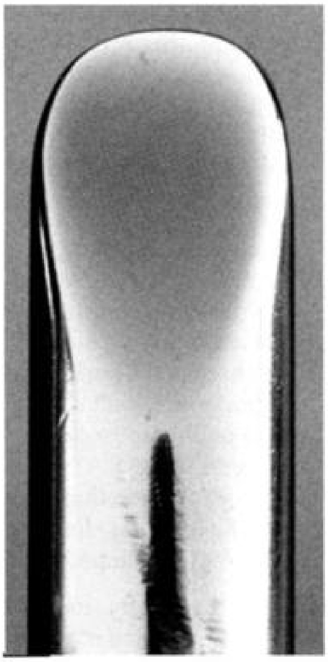

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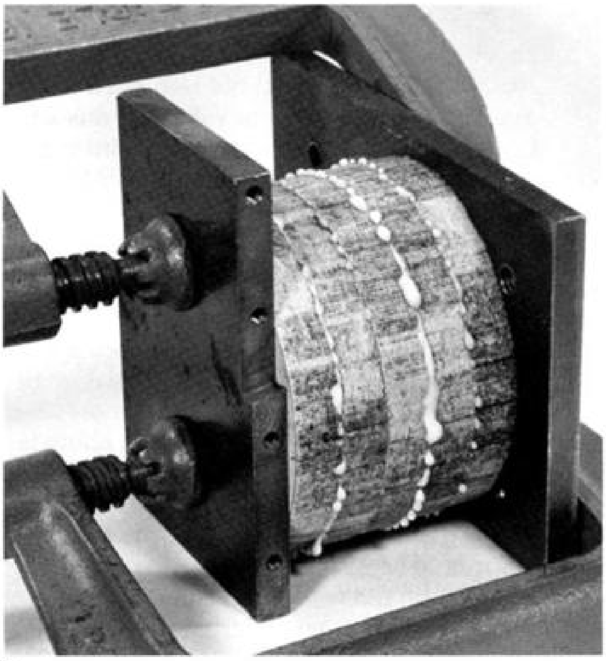

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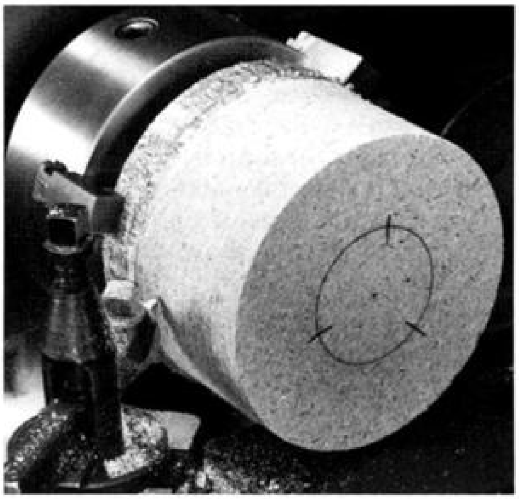

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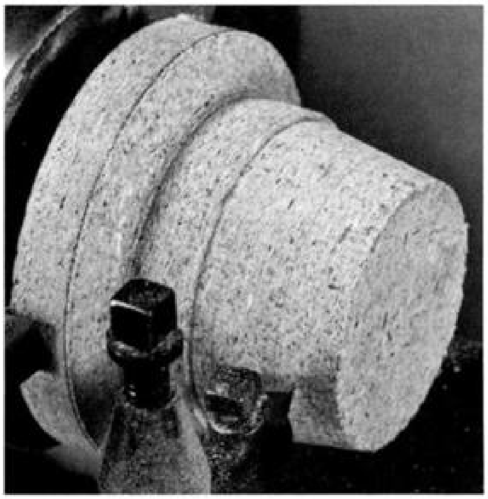

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practice and skill to know just how much force to apply with the spinning tool and when and where to apply it against the face of the revolving disc. Usually, the novice has a tendency to apply excessive force which may lead to buckling in the metal. If this buckling is severe, the piece will have to be scrapped. I've certainly ruined my share of pieces!

If you use either copper of brass for the disc, it will have to be annealed perhaps eight or ten times during the spinning operation. These metals will harden during the bending and stretching process of spinning, and must then be annealed to soften the metal again. Basically, annealing is accomplished by heating these metals to 1000° and plunging them in cold water – more later about this subject. Soft sheet aluminum requires no annealing; it's a dandy metal to practice with – less expensive too!

Photo 2 illustrates a few of my "home spun artifacts." Yes, one is an old fashioned oilcan – its construction will be the subject of this article. Furthermore, just to prove metal spinning is possible with small equipment, we'll fabricate the oilcan with a 6" lathe! Photo 3 is a "before and after" scene, showing the "raw" materials and the completed product.

Because some ordinary soldering is necessary on the oilcan, the body will be spun from a brass or copper disc, about .040" thick and 3$\frac{7}{8}$" in diameter. Choose one of the metals most readily available to you. Also visible in the photo is the entire end cover or lid cut from an ordinary 10$\frac{3}{4}$ oz. soup can; it will serve as the bottom for the oilcan. Rim diameter on the end of the can should be 2$\frac{21}{32}$". The oil spout is machined from a solid rod of $\frac{3}{4}$" aluminum or brass about 3$\frac{3}{16}$" long. The internally threaded oil filler hole flange is turned from a $\frac{3}{4}$" diameter by 1" long length of brass or steel rod.

The wooden form over which the disc will be spun is shown in Photo 4. To the left is the "tail" block. It will be positioned between the outer face of the disc and the revolving center in the tailstock. The revolving center is essential, since it holds the metal disc in firm contact with the pattern by tailstock pressure.

The third item is the spinning tool; its overall length should be about 2 feet, two-thirds of which could be a sturdy round wood handle. Photos 5 and 6 are close-ups of the tool tip; this particular configuration is termed a "tongue" tool. The first inch or so of the tool should be hardened and polished for best results. There should be no sharp edges or corners on the tool tip; everything is rounded off.

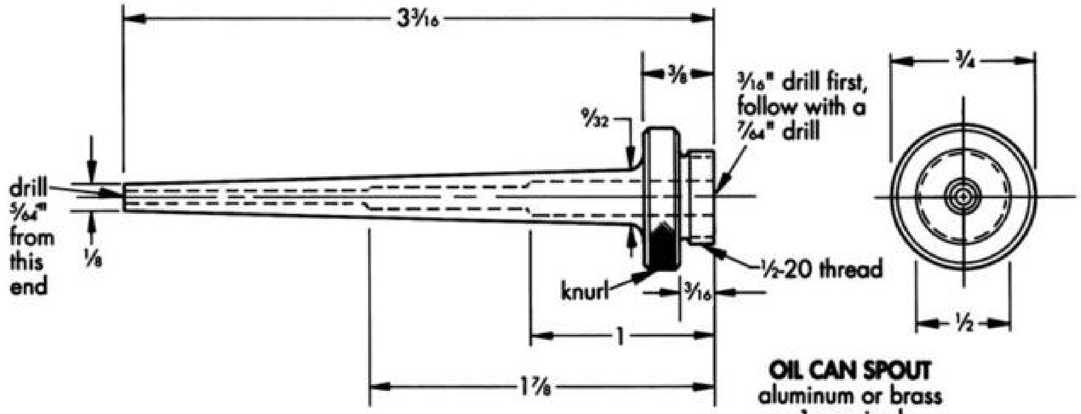
Due to an optical illusion in Photo 6, the sloping area on the face side of the tool appears to be flat – it is not! The contour should somewhat resemble the backside of a kitchen spoon. If a length of $\frac{7}{16}$" or $\frac{1}{2}$" diameter drill rod is available, it could serve for the spinning tool; or it's possible to use CRS or HRS, and case-harden the tip.

Experts seem to agree maple hardwood is the best material for the wood form; second choice is birch. For long lasting commercial production work, the forms are usually steel or cast iron. However, for our purposes, if nothing better is available, use any type of fine grained wood that's not too soft; in fact, my wooden forms were made from layers of $\frac{1}{2}$" thick particle board glued together (Photo 7). After the glue has dried, the blank is mounted in the lathe (Photo 8). According to professional metal spinners, this method of gripping the wooden form is not the best procedure; however, for us, it's the easiest way. Incidentally, professionals call the wooden form a "chuck." I'll refrain from doing that; it sounds a little redundant to say "chuck up the chuck in the chuck."

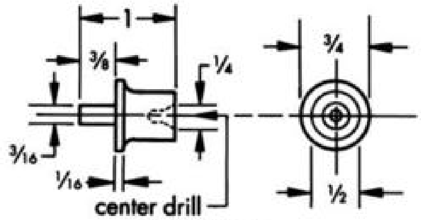
When machining the wood form, use the highest RPM available. Face off the end of the blank and take a light cut to true up the diameter. Keep your tool bit razor sharp. Notice the three pencil cross marks on the 1$\frac{1}{2}$" diameter circle. It's advisable now to remove the wood form from the lathe and drill and screw in three 1$\frac{3}{4}$" wood screws at the marked area – insurance that the glued sections will not part. The form is then reversed in the chuck and cut down to the proper diameters (Photo 9).

Finally, carefully machine the "dome" curve on the end of the blank. There is nothing critical about the curve, except to make it free of any humps or hollows. Don't attempt to file it to shape. It'll be out of round for sure, if you do. Use coarse emery paper to remove any grooves or ridges left by the tool bit. Then smooth the form with fine emery paper. Notice the $\frac{3}{4}$" diameter circle on the end of the form in Photo 10. The area within the circle should be left flat. Finally, center drill and then drill a $\frac{3}{16}$" hole about $\frac{5}{8}$" deep; it will act as a guide for positioning the tail block and disc.

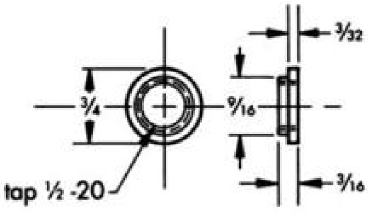
Some practical method for easily heat treating the copper or brass disc should be devised. If you have a small electric kiln or furnace, no problem. The heat from a gas furnace could also be applied by suspending the work over the flame with wires. An acetylene torch would also work by adjusting the flame to a


3³⁄₁₆
³⁄₈
⁹⁄₃₂
³⁄₁₆" drill first, follow with a ⁷⁄₆₄" drill
³⁄₄
drill ⁵⁄₆₄" from this end
⅛
knurl
³⁄₁₆
½-20 thread
½
1
1⅞

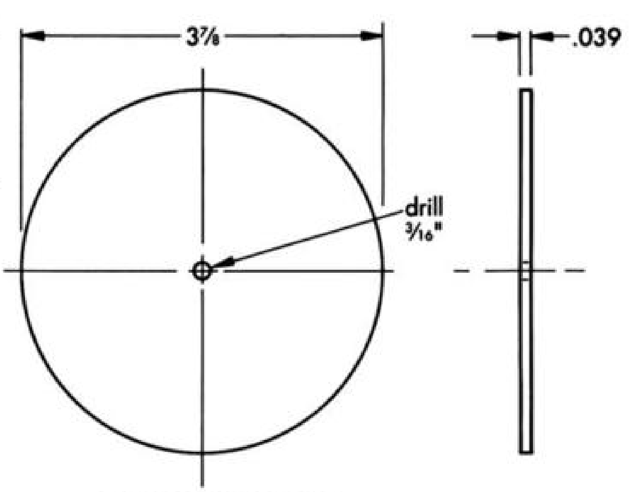
OIL CAN SPOUT
aluminum or brass
1 required


1
³⁄₈
¼
³⁄₄
³⁄₁₆
¹⁄₁₆
½
center drill

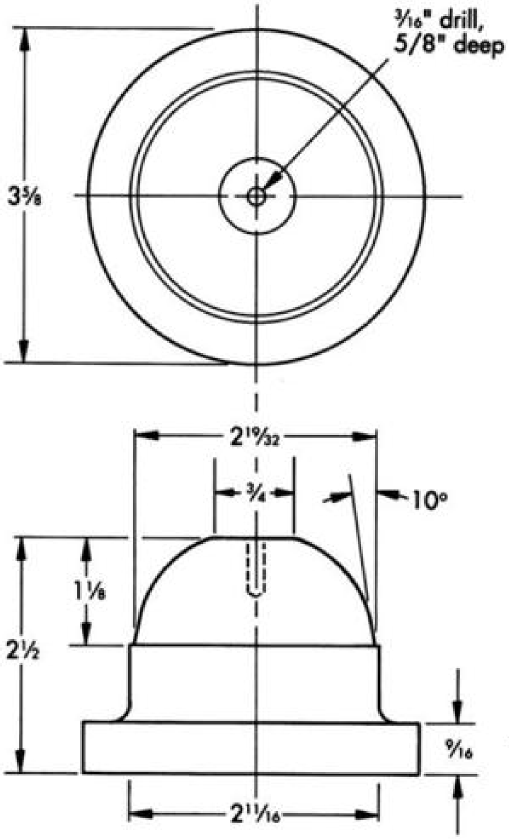
TAIL BLOCK
aluminum or CRS
1 required


³⁄₃₂
³⁄₄
⁹⁄₁₆
tap ½ -20
³⁄₁₆

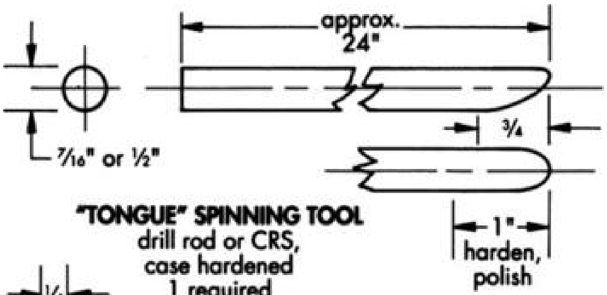
FILLER FLANGE
brass or CRS
1 required


3⅞
.039
drill ³⁄₁₆"

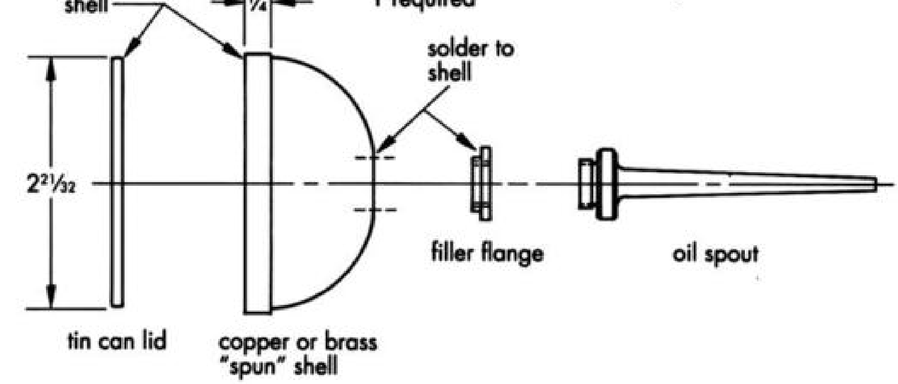
COPPER OR BRASS DISK
first choice – .039" thick
second choice – up to .049" thick
1 required

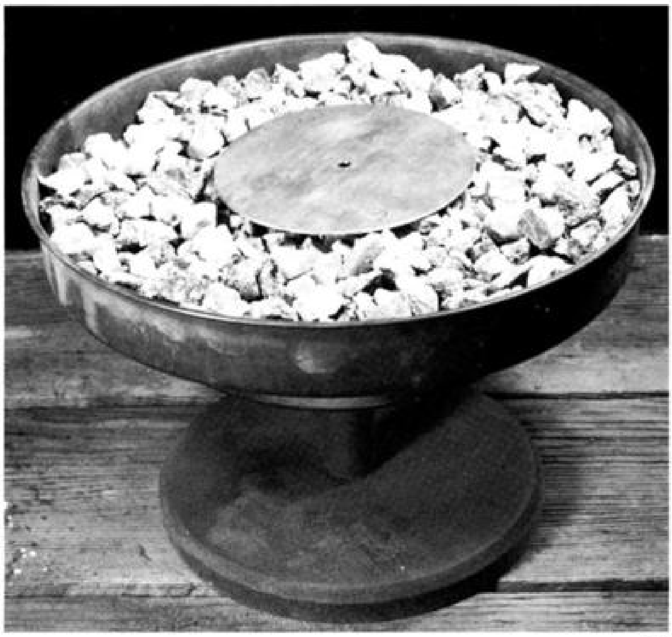

³⁄₁₆" drill, 5/8" deep
3⅝
2¹⁹⁄₃₂
³⁄₄
10°
1⅛
2½
⁹⁄₁₆
2¹¹⁄₁₆

WOOD FORM
maple, birch, etc.
1 required


approx. 24"
⁷⁄₁₆" or ½"
³⁄₄
1"
harden, polish

"TONGUE" SPINNING TOOL
drill rod or CRS,
case hardened
1 required


solder into shell
¼
solder to shell
2²¹⁄₃₂
filler flange
oil spout
tin can lid
copper or brass "spun" shell



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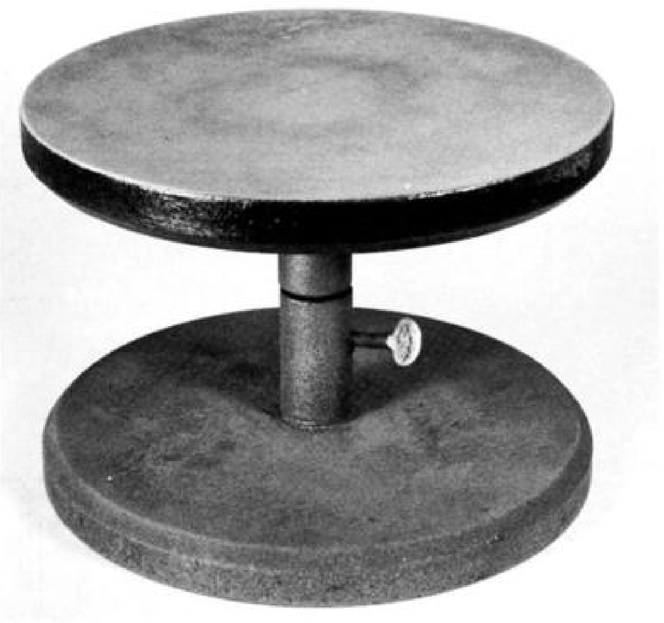


12

neutral soft "brush" flame. Now we arrive at the last resort – an ordinary propane torch. You'll need a setup similar to the one in Photo 11. It consists of an old cake or pie pan filled with pea-sized gravel and placed on a turntable. The disc can be uniformly heated by revolving the pan when applying the torch flame to the work.

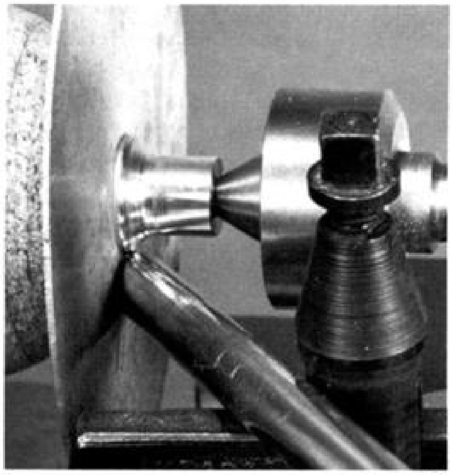
If a turntable is not available, one can be easily constructed from two 6" discs of ¾" plywood or particle board (Photo 12). A short length of ½" steel water pipe, threaded on one end, is tightly screwed into an undersize central hole in each disc. They are then filled with epoxy auto body filler. After the filler hardens, each disc is chucked in the lathe with the hub section outwards. A central ¼" hole is drilled into the epoxy filled hub until it has reached a depth of about ½" from going all the way through. A length of ¼" CRS rod is employed for the central shaft, and a 90° point is machined on one end (to act as a thrust bearing in the base hole).

The shaft is secured to the upper table by a setscrew in the side of the hub. The shaft should turn freely in the base hub, and also be long enough to keep the two hub ends from rubbing together. The thumbscrew visible in the photo merely allows you to lock the table when desired. This little table also comes in handy when spray painting model engine parts or what-have-you!

There seems to be quite a difference in opinion among experts on exactly how to anneal copper or brass. One will advise heating the metal in subdued light to 1000° or until the color of the metal turns iridescent (with rainbow colors), then plunging it in cold water. Another will say to heat it to 1200°, remove from the fire and wait a minute before plunging it in cold water. Yet another states to heat it red-hot, then plunge it in water. Well, a couple of things are certain; overheating is as bad as underheating, and the quality of the metal deteriorates slightly every time it is heated.

After sawing or cutting out the copper or brass disc, drill a 3⁄16" hole in its center. Follow by annealing the metal before attempting the spinning operation. It seems logical to assume a 1000° temperature would be close to the minimum temperature at which annealing could be accomplished properly. Just to play safe, heat the disc in subdued light until you observe iridescent colors moving around on the disc. Continue heating for another 15 or 20 second, then plunge it into cold water. The disc will now be warped somewhat, so the first trial test at spinning will be to eliminate the wobble in the disc (Photo13). If you are using a 6" lathe as in the photo, the tool post and the shank of a tool holder can serve as a support for the spinning tool. For larger lathes, make up a support bar similar to the one in Photo 1.

After the disc is in place, as shown in Photo 13, tighten the tailstock to firmly push the disc against the wood pattern – otherwise, it will slip when pressure is applied with the spinning tool. Now apply a thin coat of grease to the outer face of the disc. Auto grease is fine, or a mixture of graphite powder and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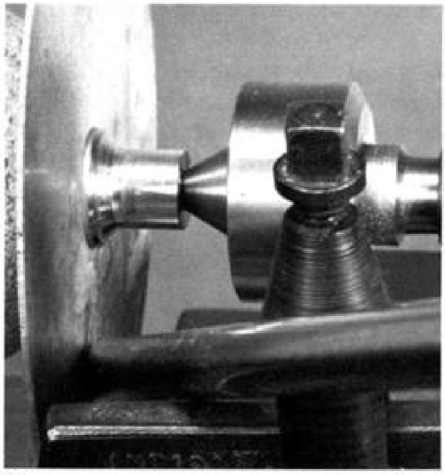
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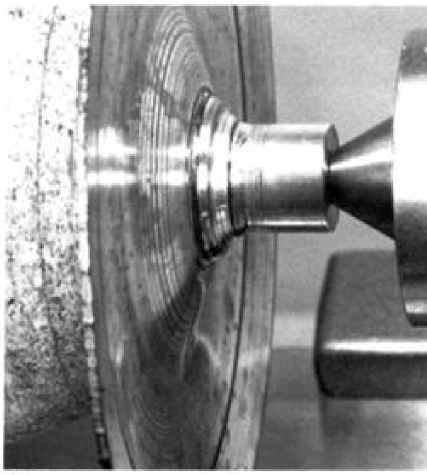
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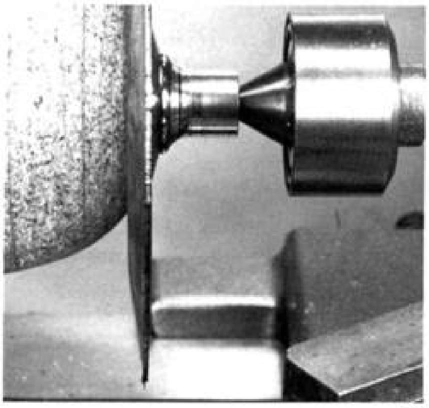
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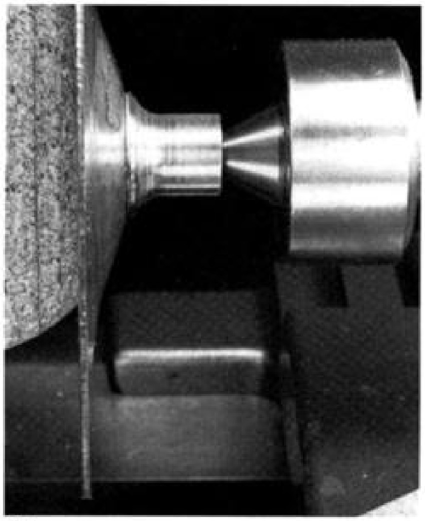
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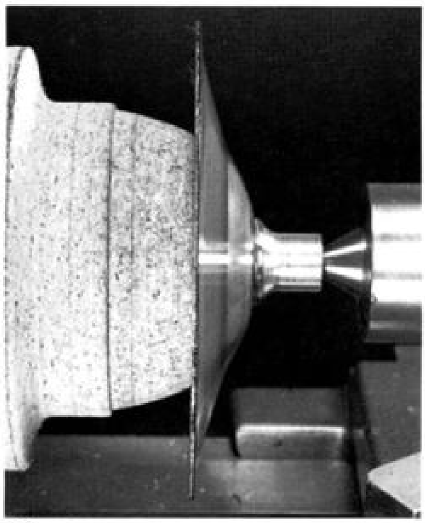
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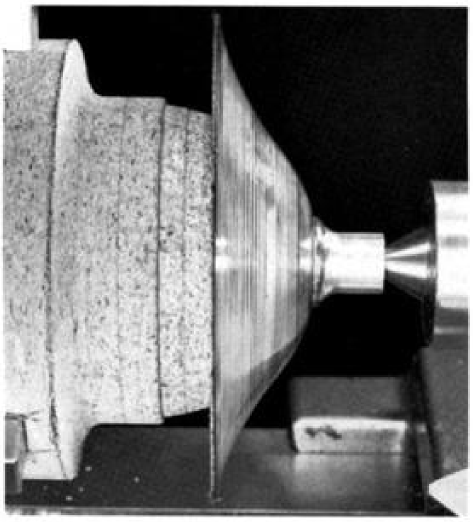
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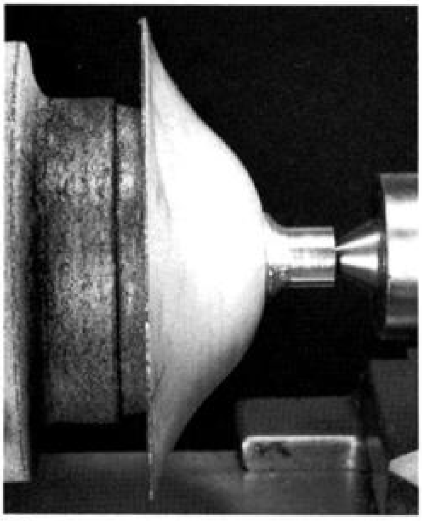
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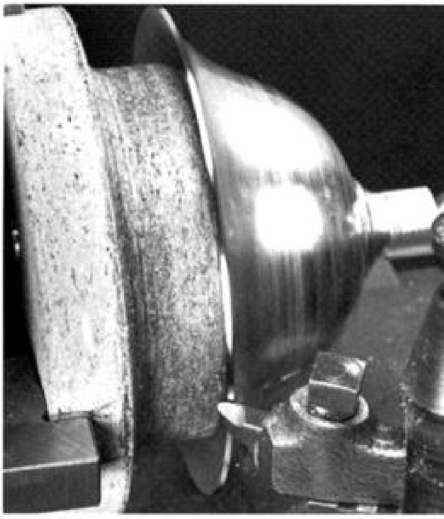

21

petroleum jelly could be used; even a soft bar of yellow laundry soap is effective.

In theory, a professional spinner would have a disc of this diameter revolve at 2000 rpm or more. The top speed of my 6" lathe is about 1200 rpm, which is more than adequate for the beginner – it's possible to spin articles even at 700 rpm. When spinning, stand to the right of the disc to avoid splattering of excessive grease onto your face and clothes.

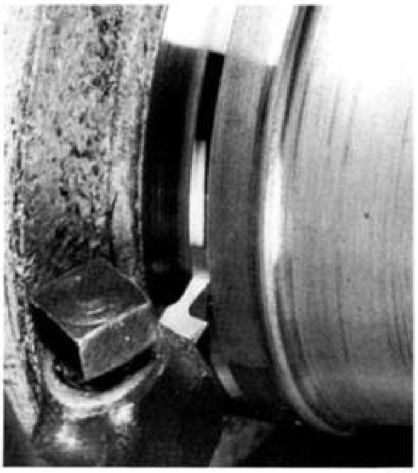
Lock the lathe carriage, start the motor and position the end of the spinning tool close to the edge of the tail block and against the disc. Slowly move the tip of the tool downward, using light pressure, until the end of the tool reaches the outer rim of the disc. If sufficient pressure was applied, the disc will now have very little wobble left, but if it does, repeat the process, exerting a little more force with the tool.

Now begins the actual process of convincing the disc to assume the shape of the wooden form. Remember, as side pressure from the tool is exerted against the work, the disc is forced to flex back and forth with every revolution. Now, the ¾" diameter of the tail block holds that portion of the disc rigid, so the major amount of flexing occurs just beyond and around, the diameter of the tail block.

If we were to continually work the spinning tool from the hub to the outer rim in an effort to bend the disc towards the form, the disc would soon crack or break in a circle close to the tail block. The best way to avoid this disaster is to repeatedly and smoothly move the tool, starting at the hub area and then downwards about halfway to the rim (Photo 14). The idea is to force the disc to conform to the curve of the pattern near the hub area as quickly as possible. Considerable tool pressure is needed to accomplish this. Once it is achieved, the disc will have to flex farther away from the hub where it is stronger and thus less apt to break. Photo 15 shows the results of this first actual spinning operation. Another view of the same thing (Photo 16) illustrates how the outer area of the disc, yet untouched by the tool, has a tendency to curl back towards the tailstock. So now work repeatedly on this area, using an outward motion with the tool all the way to the rim. The disc should then resemble the one in Photo 17.

By now, it's advisable to remove the work from the lathe and anneal it. Then return to the lathe, apply grease and continue the spinning operation. The tool should be started near the hub and moved outwards. Apply enough pressure to spin the disc tightly to the form just a little farther along the contour. Continue to move the tool outwards towards the rim, but with less pressure.

The outer area of the disc must now be spun into a slight "cone" shape (Photo 18), so concentrate the tool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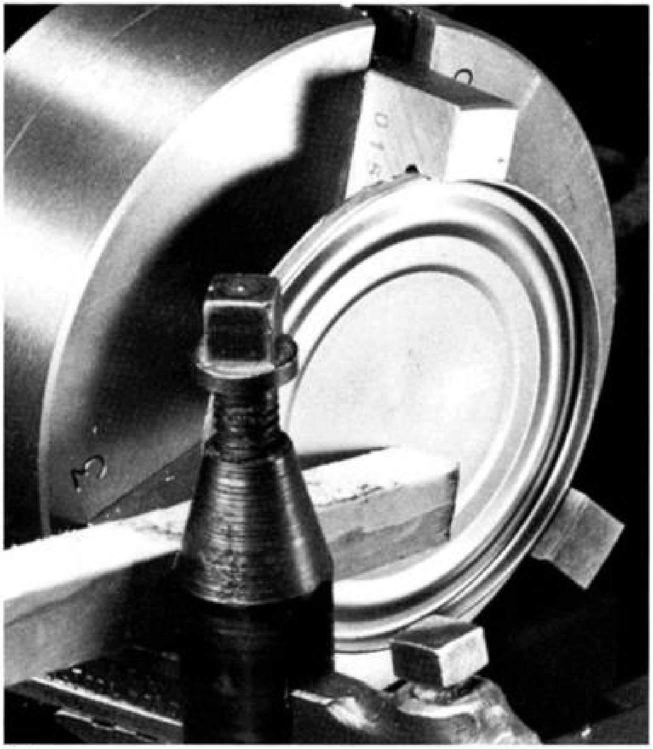
23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movement in the area of the disc not laid down tight to the form. If excessive tool pressure is used, and too quickly, when attempting to force the disc to the left, the metal may begin to buckle slightly in an area about ⅝" or ¾" from the rim. If you feel this vibration transmitted through the tool handle, ease up on the tool pressure, or immediately anneal the work.

After the disc is "coned," anneal again and continue spinning the metal a little farther down onto the form. Try to maintain a smooth sweeping curve on the shell, as indicated in Photo 19. By now, you should be able to tell when to anneal the work. Whenever the spinning tool fails to make much of an impression on the shell, it's time to anneal. Notice in Photo 20, the dull, non-glossy appearance of the shell; it has just been annealed.

From now on, as we approach the final stages of spinning, remember not to spin the shell too tightly onto the major diameters of the form. If this happens, it's difficult to remove the shell. This problem can be eased somewhat by coating with graphite powder the remaining portion of the wood form still visible in Photo 20.

As the spinning continues, it will soon become evident there's a surplus of material in the shell (Photo 21). So trim back some of the obvious surplus; this will also ease the final spin-down operation. Leave enough surplus so when the shell has been spun down completely, the rim of the metal will extend about ⅜" to the left of the little step shoulder on the wood form. This will allow surplus for trimming the base rim on the shell to about ¼" wide (Photo 22).

After completion, pull back the tailstock support and attempt to remove the shell by hand. If this fails, reinstall the tailstock support and grease the shell again. Run the spinning tool with medium light pressure over the entire shell; this will usually stretch the metal slightly to ease removal. Another option is to heat the shell to about 200° with a torch. As a last resort, carefully pry off the shell with a screwdriver.

If you wish to smooth the shell surface, slip it back onto the wood form just tight enough to avoid slipping while rough sanding out any rings or grooves. After eliminating any flaws, use a finer grit paper, perhaps 280 grit, then 400 grit, and finally 600 grit. Now set the shell aside.

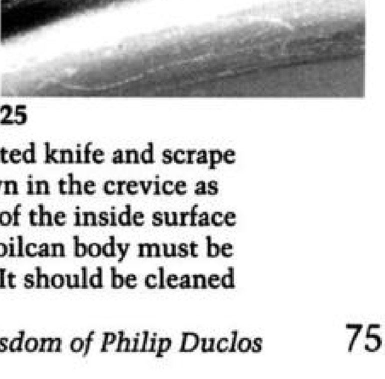
Begin work on the tin can disc, which will become the bottom section of the oilcan. Use tin snips to cut the entire bottom disc from the tin can. Trim the surplus wall of the can down as close to the bead on the rim as possible.

As you know, this type of oilcan has what might be termed a "diaphragm" bottom. When pressure from the thumb is exerted in the center of the bottom disc, it will "click" inwards slightly, and when thumb pressure is removed, the disc "clicks" back to its original position. Referring to Photo 23, this clicking action is about to be installed in the can lid. Only the circular flat area in the central portion of the lid will be touched.

Chuck up the lid with the outside face of the can lid facing outward. The spinning tool is a piece of ordinary wood about ½" square and about a foot long. The idea is to spin a slight hollow into the flat area of the lid. This is quickly and easily accomplished by starting the lathe, applying light pressure with the wood stick at the center of the lid and slowly moving the tool down to the edge of the flat area (Photo 24). Repeat this a couple of times. Stop the lathe and examine the surface of the lid. If enough pressure has been applied with the tool, the surface will now be slightly concave.

Remove the lid from the lathe and place it on a flat surface, with the inside face uppermost. The central area on this side of the lid should now be slightly convex. Press your finger down on the center of the lid and it should "click" downwards and then "click" back up when pressure is released. If it does not respond in this manner, repeat the spinning process, adding more tool pressure.

The lids on each end of a modern "tin" can are not tin plated. The inside surfaces of a food can are coated with a light tinted type of non-metallic material. The exterior face and rim of the lids are covered with a transparent coating. This coating must be removed from the entire rim area of the lid, and also from the inside surface of the lid back from the rim about ¼", before it can be soldered into the body shell. Scrape the coating with a knife, or sand it, or use a wire scratch wheel. Then closely examine the inside surface of the lid near the rim (Photo 25).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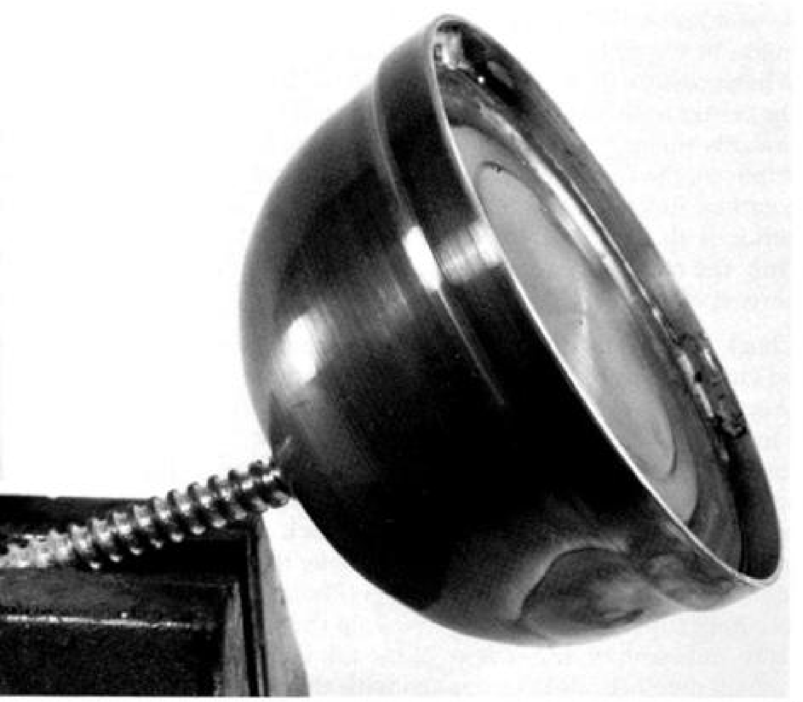
Use a razor blade or pointed knife and scrape off the coating as far down in the crevice as possible. Also, a portion of the inside surface near the base rim of the oilcan body must be scraped or sanded clean. It should be cleaned



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down to and including the little step shoulder where the tin can lid will rest.

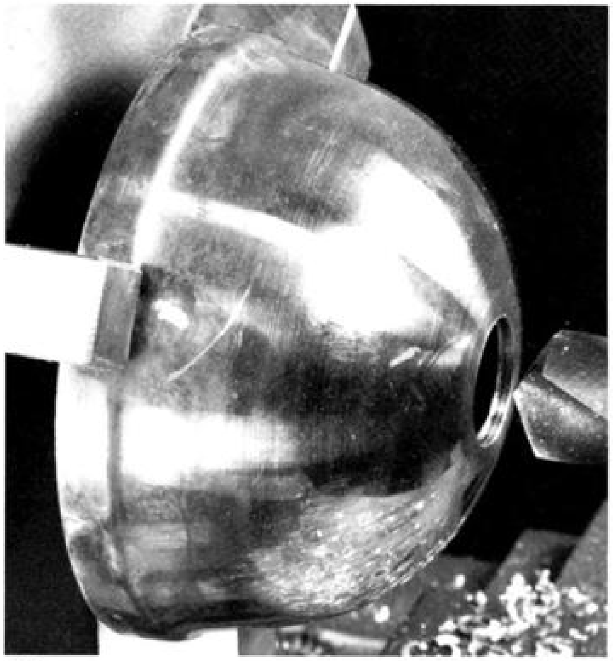
Now position the oilcan body upside down. The tin can lid is placed in the body with the surface that originally was inside the can now facing outwards. Flux around the rim and spot solder the lid in place about every 90° around the circumference. Use a propane torch adjusted to a short flame. Now position the work at an angle as shown in Photo 26, onto the tip of a long wood or lag screw.

Preheat the body with a short torch flame and then concentrate the heat near the lowest area of the base rim. Apply enough solder inside the rim to form a smooth melted filet about ¾" in length (Photo 27). Allow it to solidify, then rotate the work about ¾" and apply more solder next to the area just completed, blending the new solder into the previous section, and so on around. The soldering job can be smoothed later.

Transfer the work to the lathe for enlarging the hole in the top of the body (Photo 28). Either bore it out to 9⁄16", or drill it to 9⁄16" by gradually increasing the drill sizes. To avoid having the drills seize in the hole, keep the quill lock on the tailstock semi-tightened while drilling.

Begin work on the oilcan spout (Photo 29). Cut the blank rod to the proper length. Form the knurl, cut the threads, and then drill a 3⁄16" hole about 1" deep. Follow with a 7⁄64" drill to a depth of 1⅞" from the outer end of the work. Set the

27



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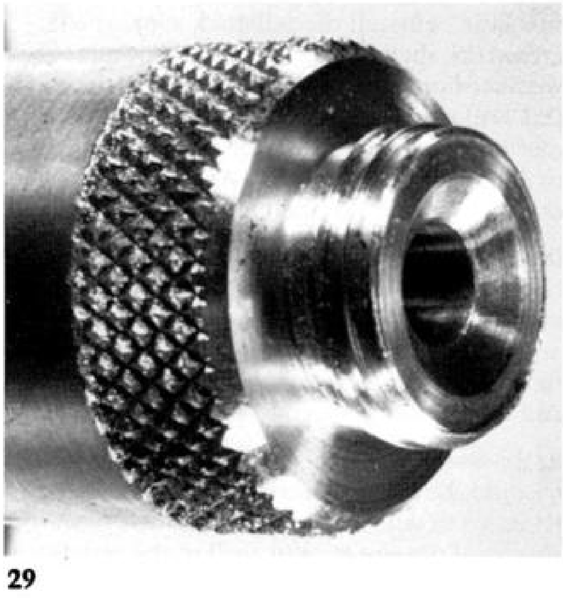

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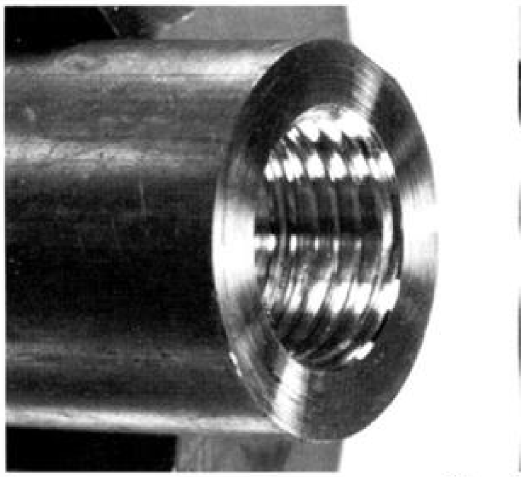

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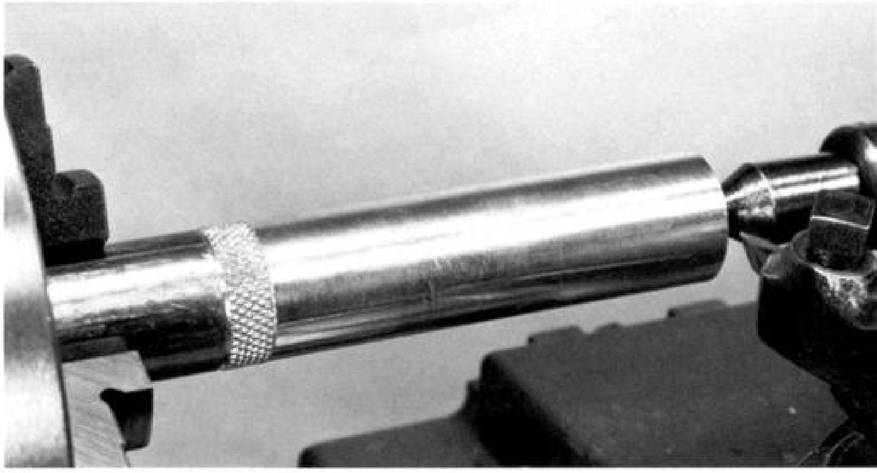


31

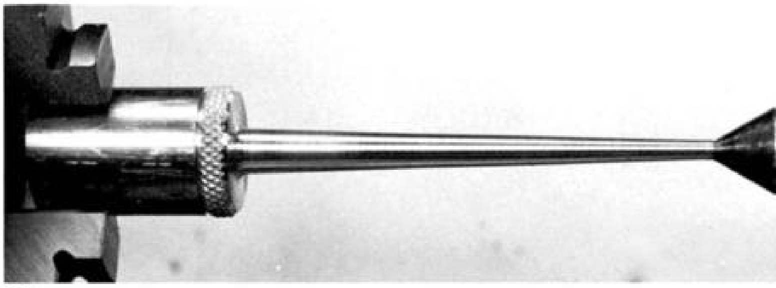
piece aside for the moment. Chuck up the material for the filler-hole flange (Photo 30). Drill and tap the hole about 3/16" deeper than necessary. Now take the partially finished oilcan spout and screw it into the unfinished filler flange (Photo 31).

Drill a No. 1 center drill hole in the end of the work for tailstock support. Machine off most of the surplus material along the spout down to a diameter of approximately 5/16". Set the compound slide to 1 1/2° and machine the taper (Photo 32), readjusting the angle of the compound slide if needed. Finally, using a 5/64" drill in the tailstock, drill a hole in the end of the piece deep enough to meet the previously drilled hole started from the opposite end. Smooth the spout before unscrewing it from the partially completed flange – then finish the filler flange and follow by soldering it into the oilcan body.

Chuck up a short length of 1/2-20 threaded rod and screw the oilcan body onto it (Photo 33). Use a small piece of coarse emery cloth to smooth out the soldering job in the oilcan base. Finally, polish the tin can bottom with fine emery paper.

That's it! We have just "scratched the surface" of metal spinning. There's great potential for learning and creating in this interesting craft.

At least from now on, I'll bet you'll look with more respect at every lowly oilcan you see – but you'll find none more beautiful than yours. Give metal spinning a whirl!



32

33

BILL OF MATERIALS

NO.	ITEM	MATERIAL	UNFINISHED SIZE
1	Wood form	maple, birch, or particle board	3-3/4" square × 2-3/4"
1	Tongue spinning tool	drill rod or CRS	1/2" diameter × 24"
1	Tail block	aluminum or CRS rod	3/4" diameter × 1"
1	Filler flange	brass or CRS rod	3/4" diameter × 1"
1	Metal disc	copper or brass	.039" × 3-7/8" diameter
1	Spout	aluminum or brass rod	3/4" diameter × 3-3/16"
1	Tin can bottom	steel	2-21/32" diameter

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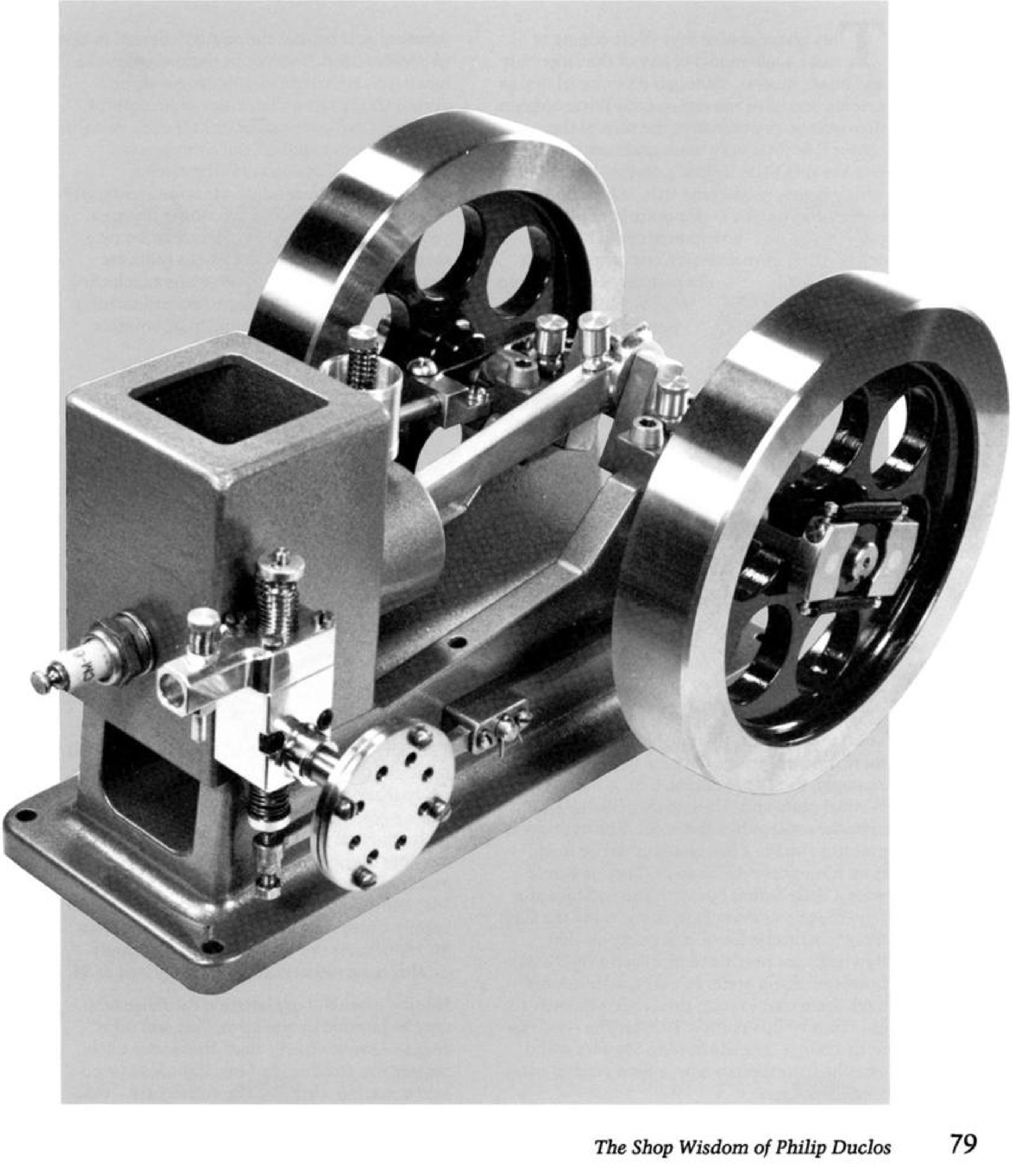
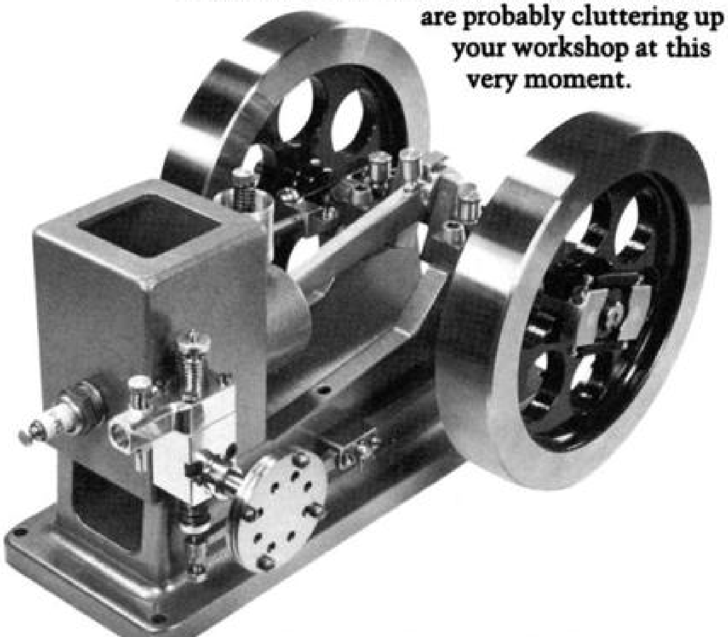
Hobby Projects



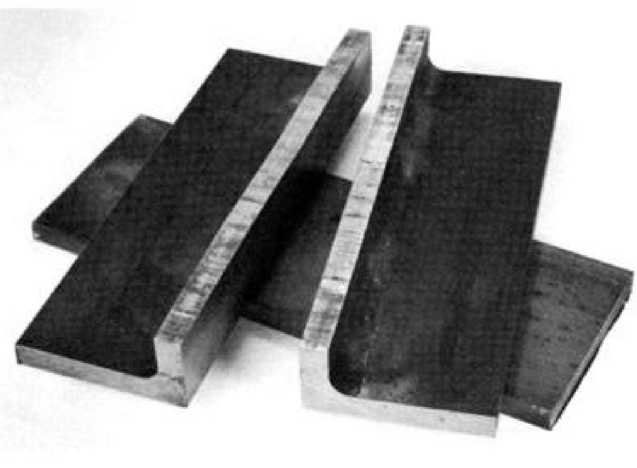
Odds 'n Ends Hit 'n Miss Engine

This water-cooled four-cycle engine is not a scale model of any of the large "hit and miss" motors, although its unusual design is reminiscent of the famous old Witte engines that were so popular after the turn of the century. Several very basic goals are incorporated in this little engine's design, one of which is espoused in the title "*Odds 'n Ends* Hit 'n Miss Engine" – for quite literally a large portion of this 1" bore motor could be constructed from ordinary bits of metal that are probably cluttering up your workshop at this very moment.



More to the point, though, is the fact that there are no castings to make or purchase! For example, the entire engine base is built from ⅜" steel plate and ⅜" angle iron (Photo 1). The cylinder coolant block is steel. The cylinder is cast iron, but as a last resort could be made from hot or cold rolled steel. True, it would wear a little faster, but with the addition of a 1-to-25 ratio of two-cycle motor oil to the fuel, there's little chance of it freezing up. The flywheels are machined from solid steel disks; however, if you prefer to make patterns and have them cast in iron, then that's the way to go. To carry this point a little farther – anyone with a home shop aluminum foundry could cast the flywheels in zinc, a heavy metal ideal for this purpose.

Another goal behind the engine's design is ease of construction. You're *not* required to make fancy jigs or fixtures in order to machine a part, nothing more than a few ordinary stub mandrels and one small gage! I'll even detail a *simple* way to machine the timing gears! Okay! Okay! If visions of pitch circles, addendum and dedendum measurements, and expensive gear cutters are flashing through your mind, relax! You don't have to know a thing about making gears. These gears are formed with a *single* flycutter, the machining of which is a simple, straightforward milling operation; *no* brain numbing mathematics are required.



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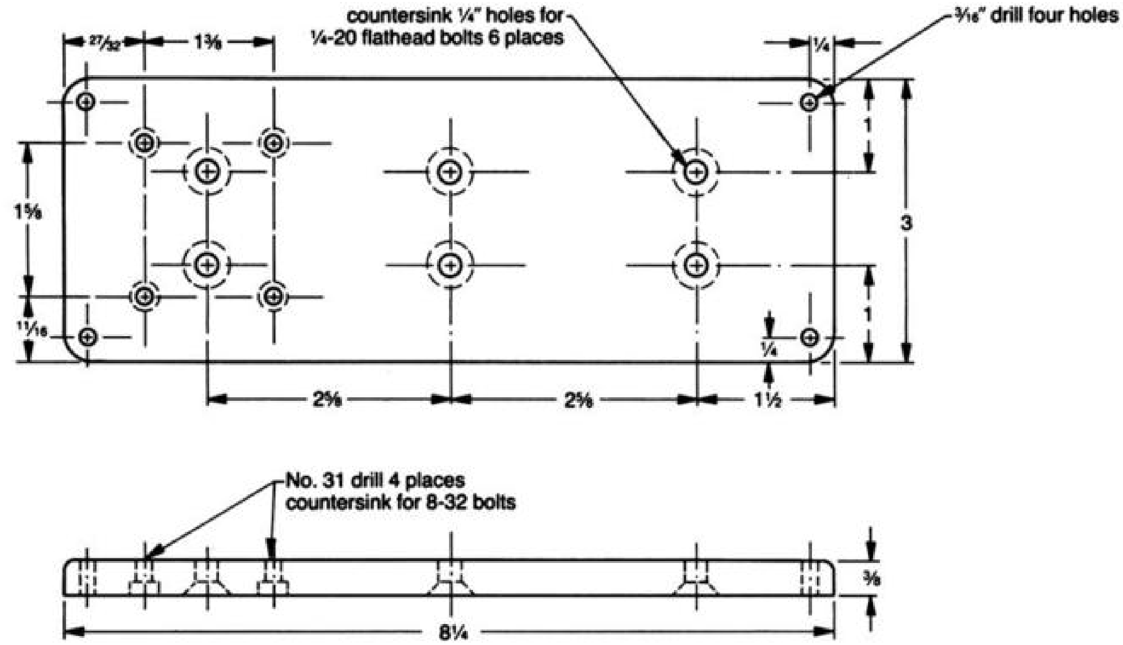
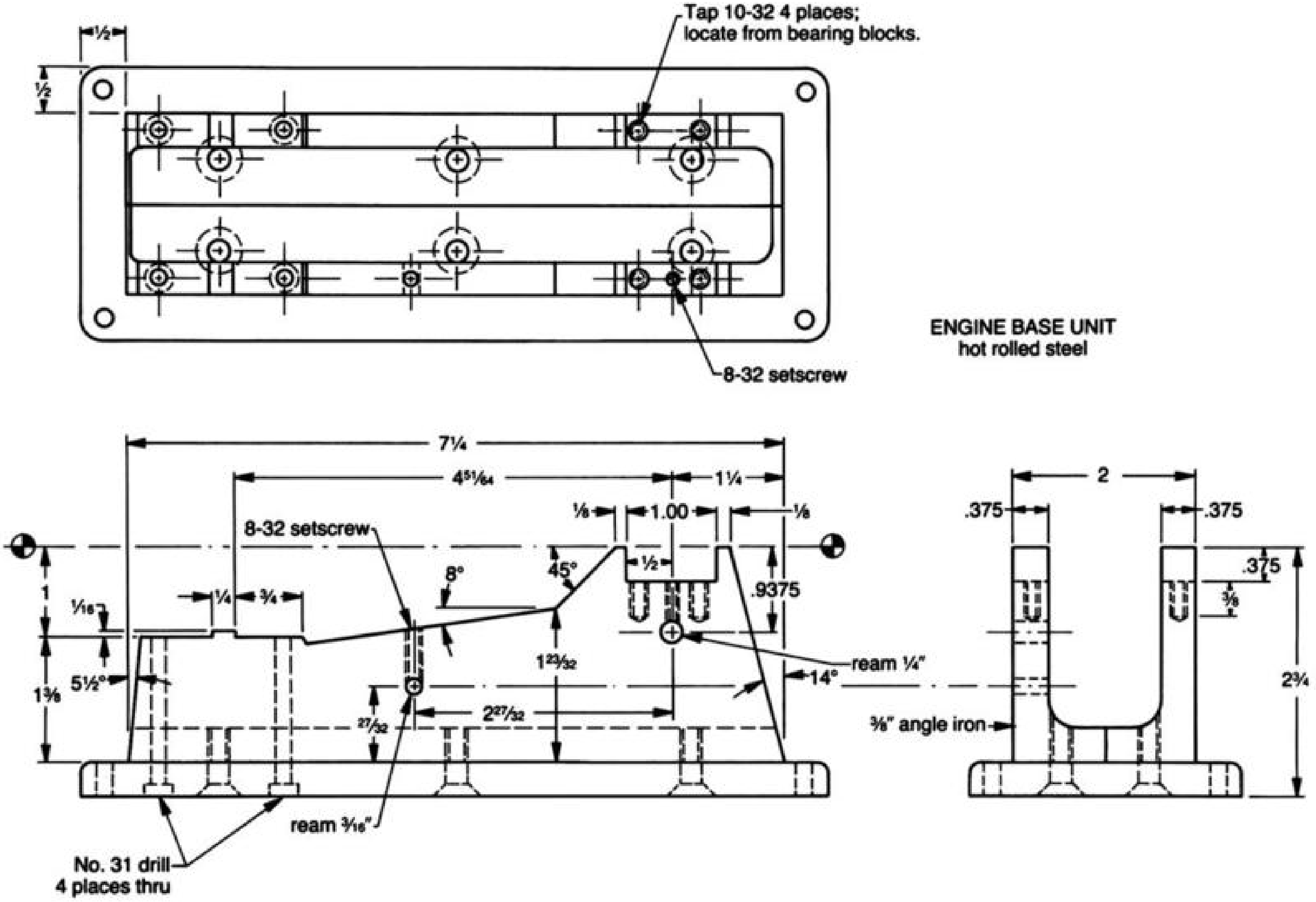
Though it's possible to make your own piston rings and spark plugs, I opted to purchase ready-made ones. These items, along with timing gears, flywheels and various supplies, including cast iron rods (from which the cylinder of this engine could be made), can be purchased from Cole's Power Models, Inc., Box 788, Ventura, CA 93001 – or from Power Model Supply Company, Route 1, Box 177, De Soto, MO 63020. At the time of writing, a supply catalog from either company was priced at $4.

Finally, a word of explanation for those who may be puzzled by the term, "hit and miss" engine. Under a heavy load, these four-cycle motors fire steadily; but in a light load or *no* load situation, they fire intermittently – that


countersink ¼" holes for ¼-20 flathead bolts 6 places
³⁄₁₆" drill four holes
27/32
1⅜
¼
1⅝
11/16
1
3
1
¼
2⅝
2⅝
1½
No. 31 drill 4 places countersink for 8-32 bolts
⅜
8¼

ENGINE BASE PLATE
hot rolled steel

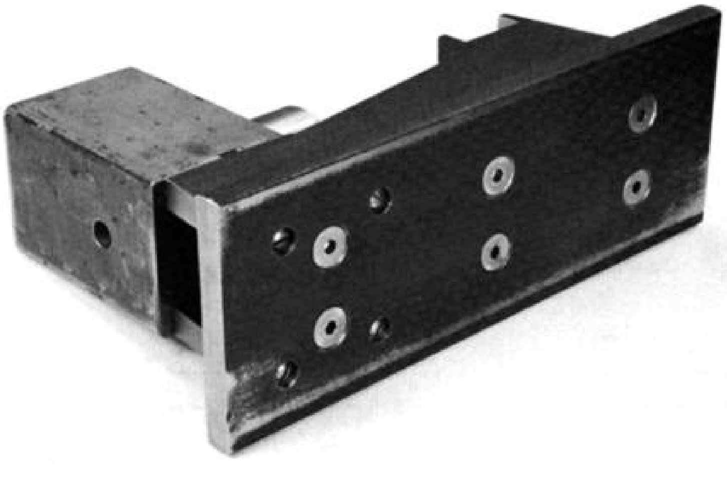

Tap 10-32 4 places; locate from bearing blocks.
½
½
8-32 setscrew
7¼
4⁵¹⁄₆₄
1¼
⅛
1.00
⅛
8-32 setscrew
½
45°
8°
.9375
1
1/16
¼
¾
5½°
1⅜
1²³⁄₃₂
ream ¼"
14°
27/32
2²⁷⁄₃₂
ream ³⁄₁₆"
No. 31 drill 4 places thru
2
.375
.375
.375
⅜
2¾
⅜" angle iron

ENGINE BASE UNIT
hot rolled steel

is, after a single firing, the motor will continue working for a number of revolutions by the sheer momentum of the two outsized flywheels. When the RPM falls to a certain point, the governor kicks in and the motor fires once again. Perhaps it's this unique cycling action that makes the "hit and miss" engine so fascinating to watch and to hear!

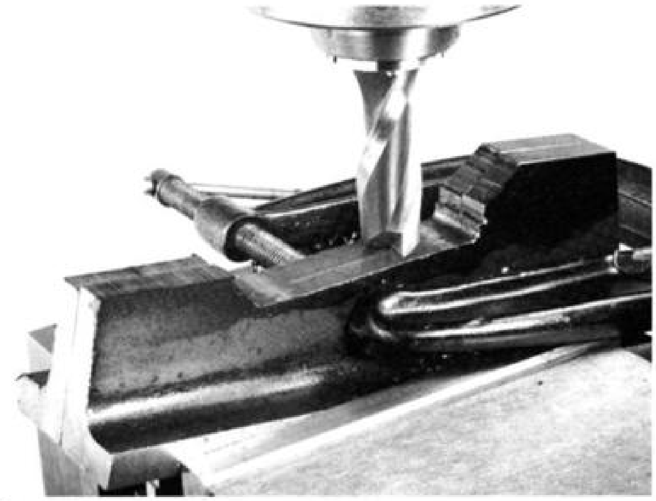
If you're looking for a project that's both fun to do and economical, this one certainly qualifies! With careful workmanship you'll have a sparkling jewel of a motor. What a thrill when you first spin the flywheel and your little creation springs to life!

Let's start with the Engine Base Unit. Lay out and drill all of the bolt holes in the flat base section; countersink for the bolt heads. Photo 2 illustrates how these bolts will appear after the base unit is bolted together (along with the cylinder block). Set aside the baseplate for the moment. The two upright sections of the base are cut from ⅜ × 2 × 3" angle iron. If you can't find that size, then use 3 × 3". One side of each piece is cut down to a width of exactly 1". Then, the two pieces of angle iron are clamped back to back and parallel in your milling machine vise. The 1" wide section will be uppermost and horizontal. Mill a light cut along this surface to true it up.


2

Now lay out the slanting lines on each *end* of the vertical sections of the angle iron. Mill the proper slant on each end, thus bringing the angle irons to their correct overall length. Next, clamp the two sections in position on top of the flat baseplate. Make certain they are parallel to the side edge of the baseplate. Turn this assembly upside down on the drill press and spot drill into the angle irons for the location of *all* the bolt holes, including the four that will hold the cylinder block.

Remove the baseplate, then tap drill and thread the six ¼"-20 holes in the angle irons. Once again, the angle irons are clamped back to back in the mill vise. Mill down and finish the sloping portion of the midsection (Photo 3). Next, bolt the three base parts together and proceed to machine the bearing block slots and the locating keys for the cylinder block. Naturally, the workpiece should be perfectly parallel to the table travel. Without changing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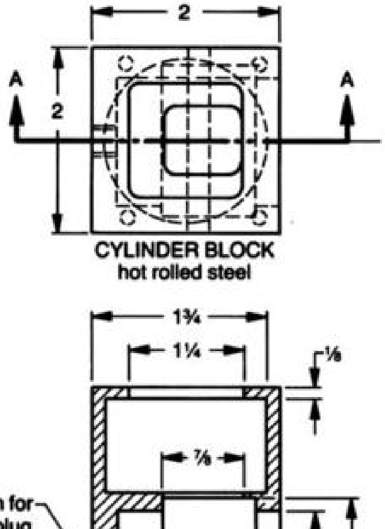
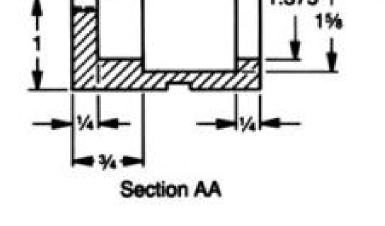
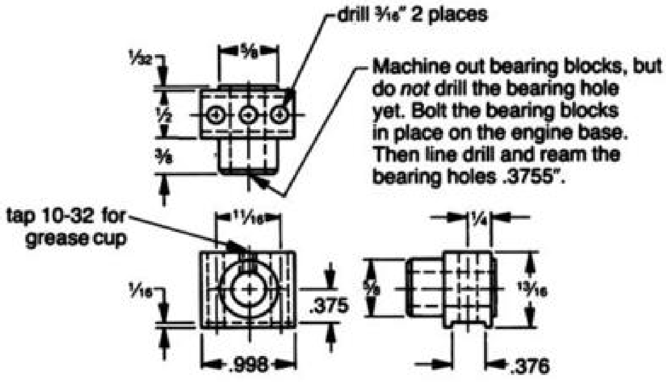


CYLINDER BLOCK
hot rolled steel



Section AA

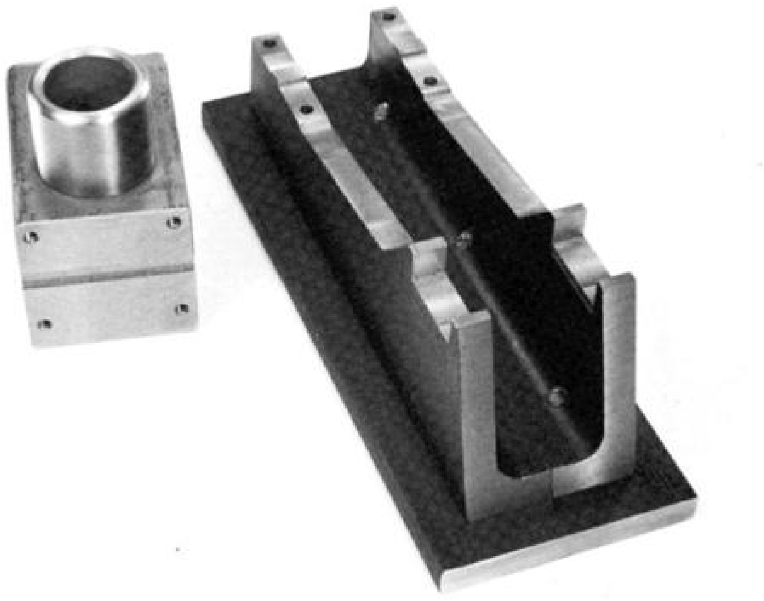


Machine out bearing blocks, but do *not* drill the bearing hole yet. Bolt the bearing blocks in place on the engine base. Then line drill and ream the bearing holes .3755".

BEARING BLOCKS
cast iron
2 required

this setup, mike the thickness of the 3/8" iron just below the bearing block slots. If it's more than .375", use the side of the end mill to bring it to size along the *inner* face of each upright just below the slot. This cut is visible in Photo 4 as a bright 1/8" wide band just below the farthest bearing block slot. Remove the work from the mill, turn upside down and finish drilling the four cylinder block bolt holes through the base unit visible in Photo 4.

Commence work on the Cylinder Block. Square up each end, then drill and bore out the hole for the cast iron sleeve (Photo 5; note the spark plug hole). Check for taper in the bored hole before finishing to size; it must be straight. Then enlarge a section of the bore to form what will be the water jacket around the cylinder. Next, machine the cast iron cylinder sleeve and press it into the block.



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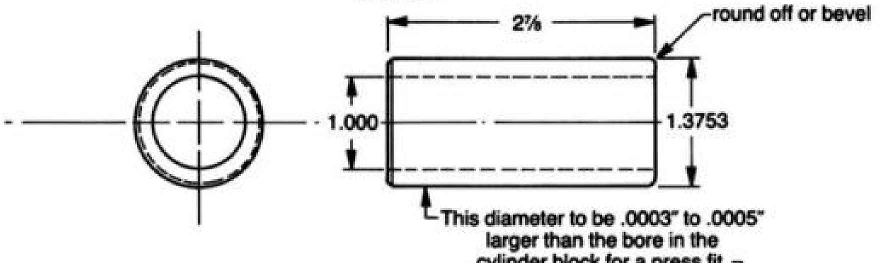
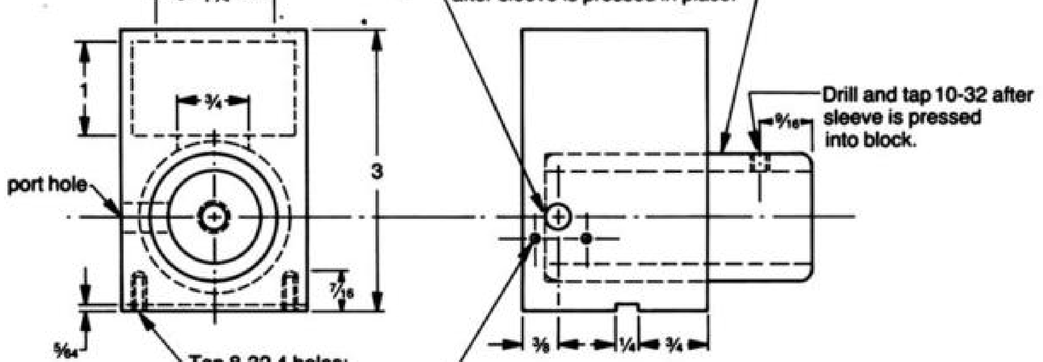
It's advisable to smooth out the cylinder bore by lapping. Machine a portion of a steel rod to a diameter that is about .002" smaller than the

CYLINDER SLEEVE
cast iron



This diameter to be .0003" to .0005" larger than the bore in the cylinder block for a press fit.

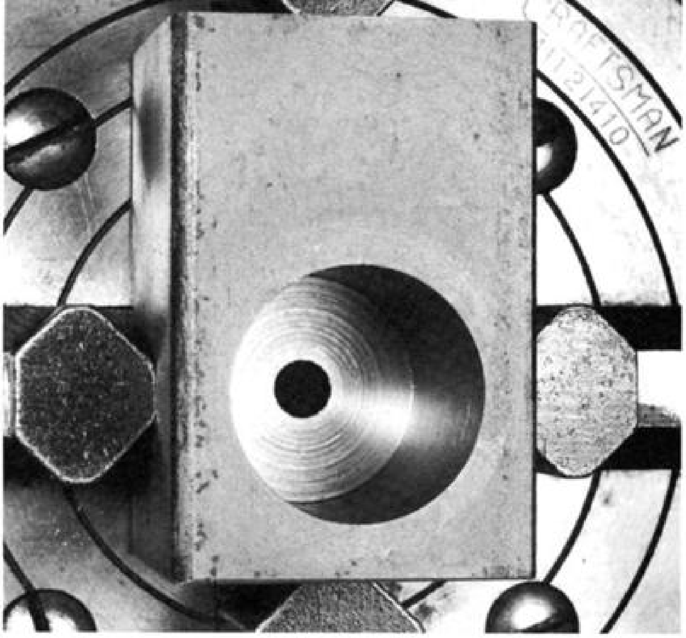
Intake-exhaust port hole: drill 9/32" after sleeve is pressed in place.



Drill and tap 10-32 after sleeve is pressed into block.

Tap 8-32 4 holes; locate from base unit.

Tap 4-40 2 places, 5/16" deep; locate from exhaust valve unit.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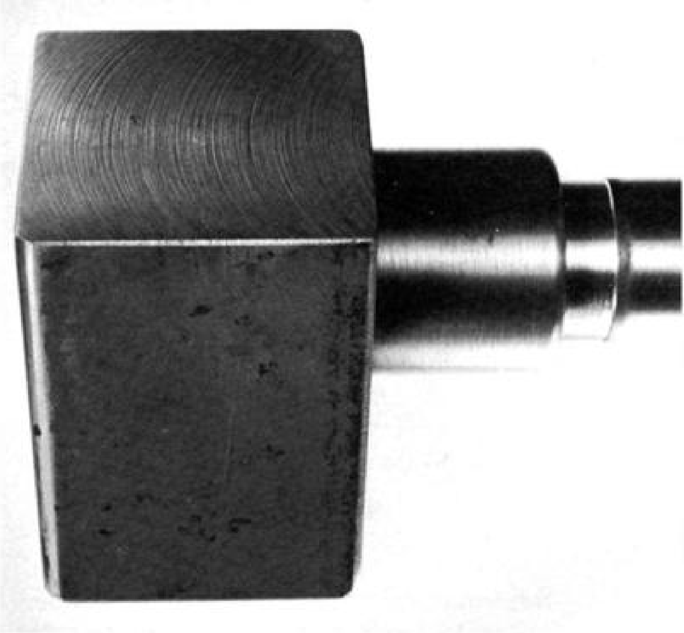

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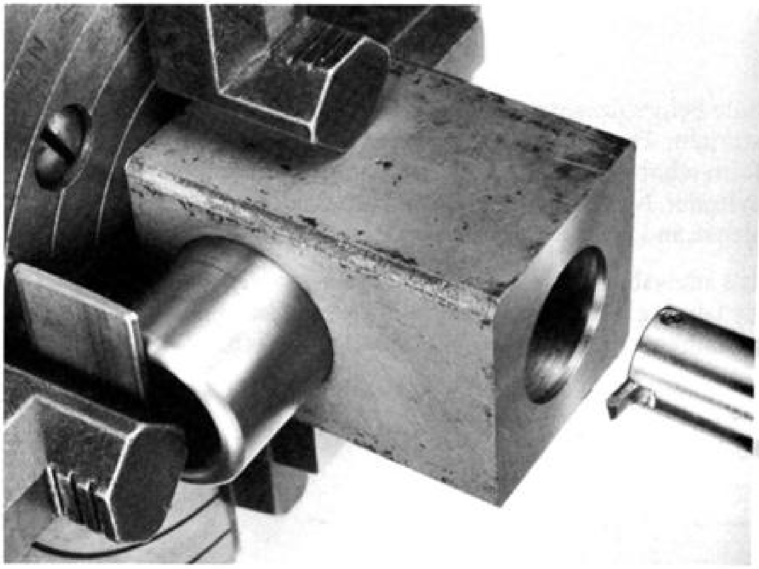

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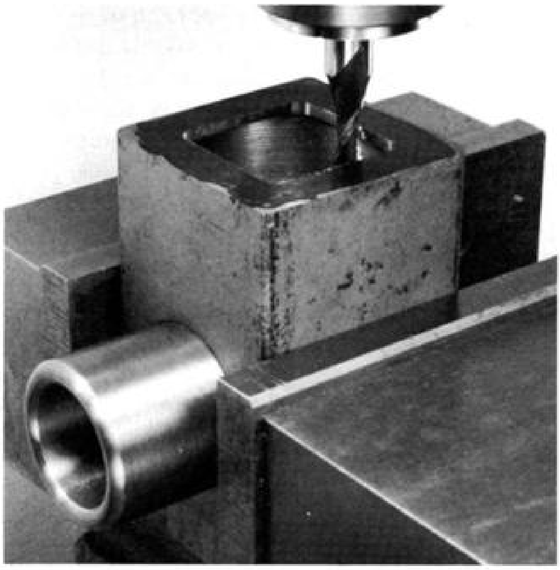

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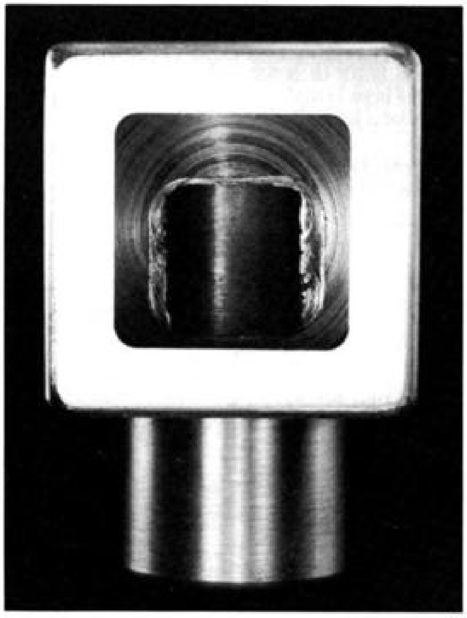

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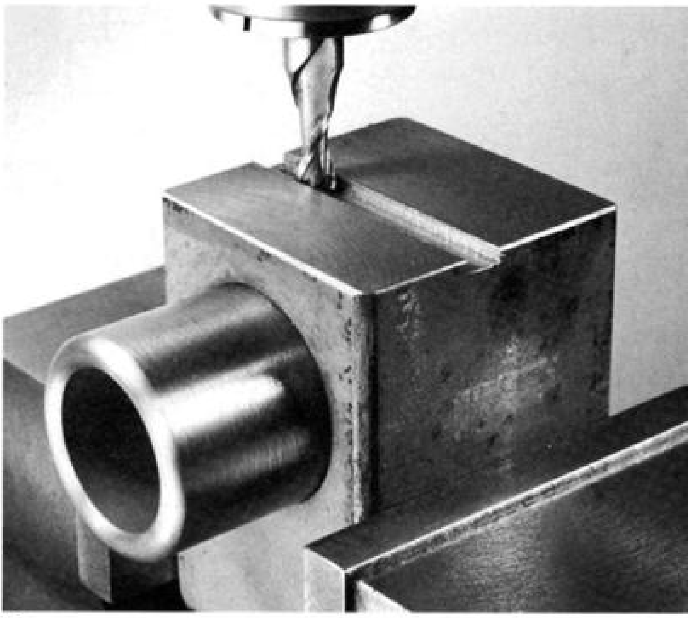

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cylinder bore. The length of this diameter should be about ⅜" shorter than the length of the cylinder. Undercut the rod a short distance behind this length. The lapping tool is primed with *fine* valve grinding compound; also, smear some around inside the cylinder.

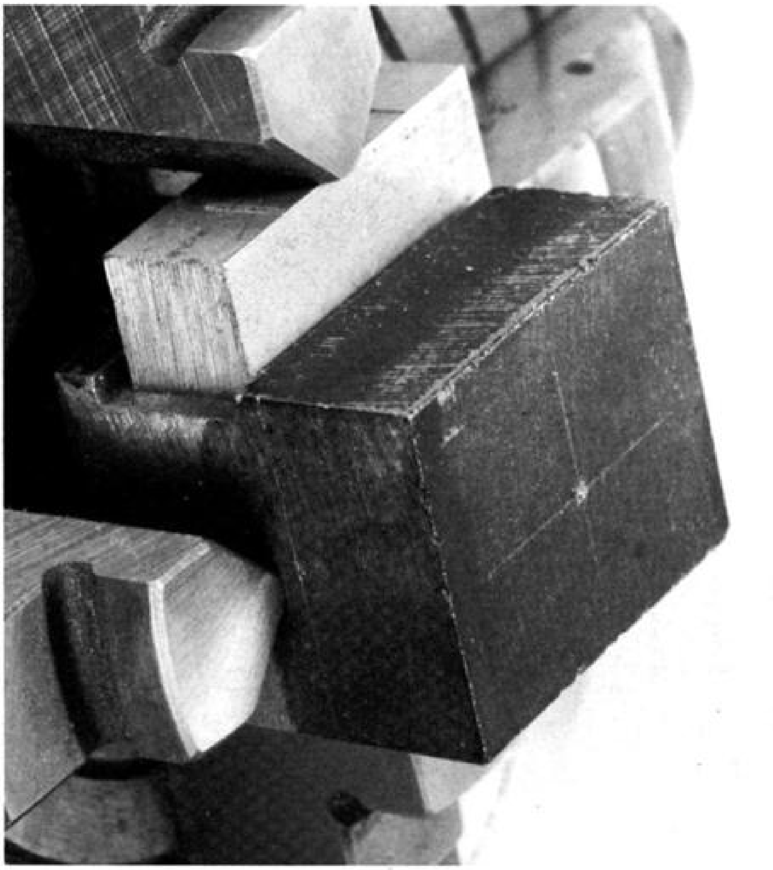
Now, with the rod chucked in the lathe, attempt by hand to push and twist the cylinder onto the lapping tool (Photo 6). It should not go on too tightly. If it begins to bind, remove the workpiece and reduce the arbor diameter by .001". Then slide the cylinder all the way onto the arbor and hold onto the work. Start the lathe – use a fairly slow spindle speed. As the lapping tool revolves, slowly slide the work back and forth about ⅜". After about a minute, stop the machine, remove the cylinder and add a little more grinding compound; repeat the process. When finished, it's important that *all* of the grit in the cylinder be removed; scrub with distillate and an old toothbrush. All portions of the cylinder wall should have a uniform gray appearance.

Although this little hit and miss engine sports the traditional squared opening in its Water Tank, the inner form of the tank is cylindrical. To accomplish this, center the square upper portion of the cylinder unit in your chuck as in Photo 7, being careful to protect the cylinder opening with a flat piece of steel. A good portion of the water tank must be machined with a boring bar through a relatively small and thin opening as visible in Photo 7. Then mill the square opening in the tank top (Photo 8). Finally, drill and mill the opening into the water jacket that surrounds the cylinder, as viewed in Photo 9. Use caution – don't mill into the cylinder sleeve!

The Cylinder unit must be aligned perfectly on the engine base – this is easily accomplished by mounting the block upside down in the mill vise. Indicate along the side of the cylinder and adjust the vise for a zero reading. Now mill the locating channel (Photo 10); make it a snug fit on the engine base lugs.

I machined the Crankshaft Main Bearings from blocks of cast iron. They could be made from tempered aluminum or bronze, brass, or even steel blocks with bronze bushings pressed in.

First, mill the shallow ⅜" wide channel in each bearing block, then drill the bolt holes. Next, the blocks are centered in the lathe as in Photo 11 with a piece of steel in the channel to protect them. Machine as in Photo 12. Do *not* drill the bearing hole at this time. Now mount



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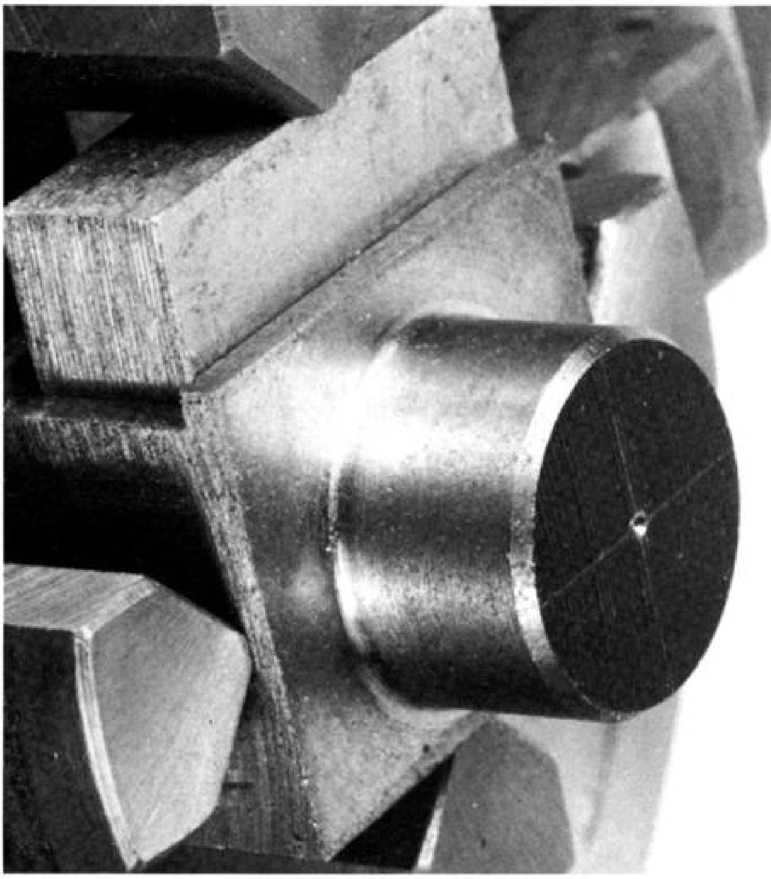

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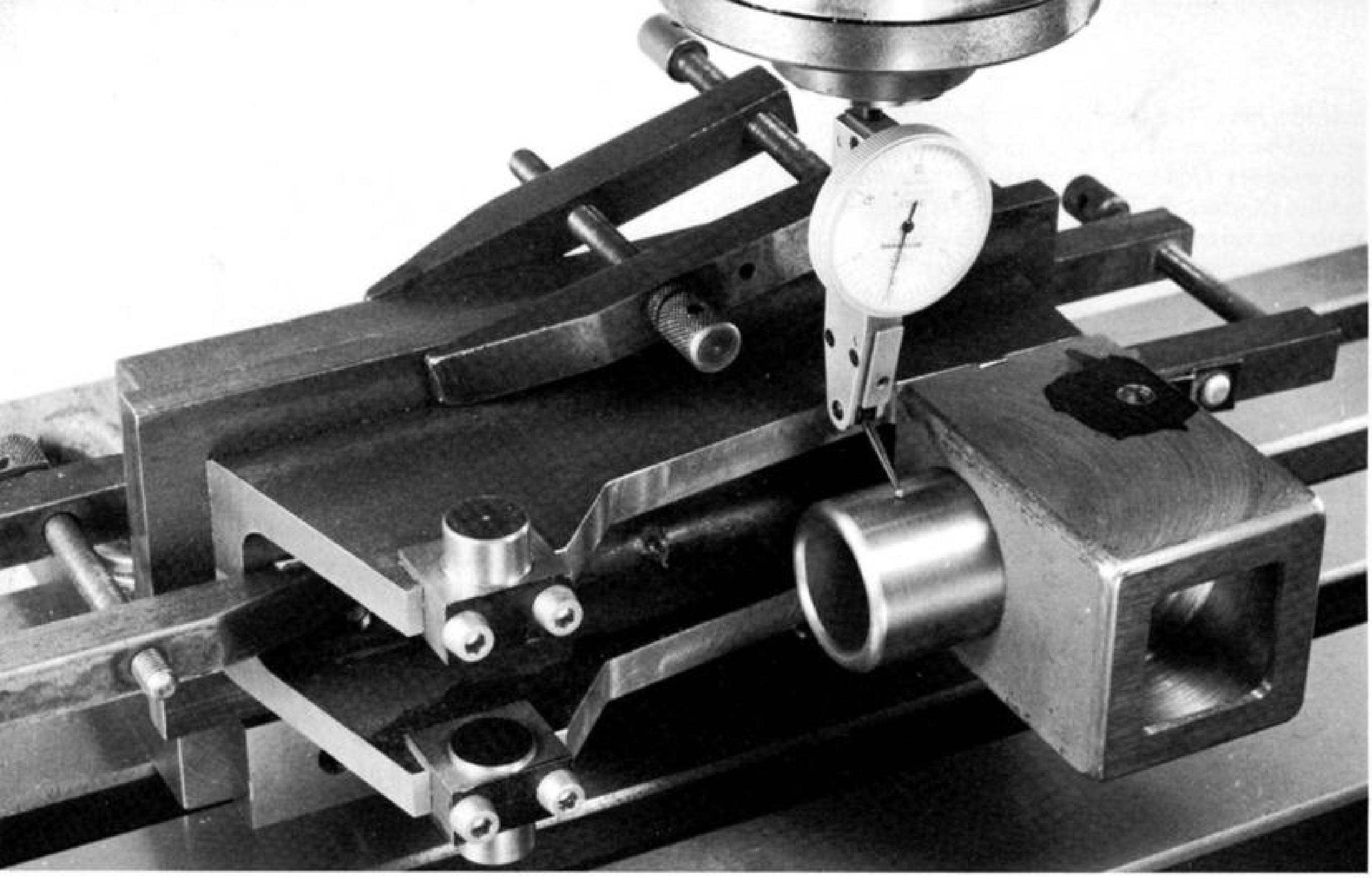

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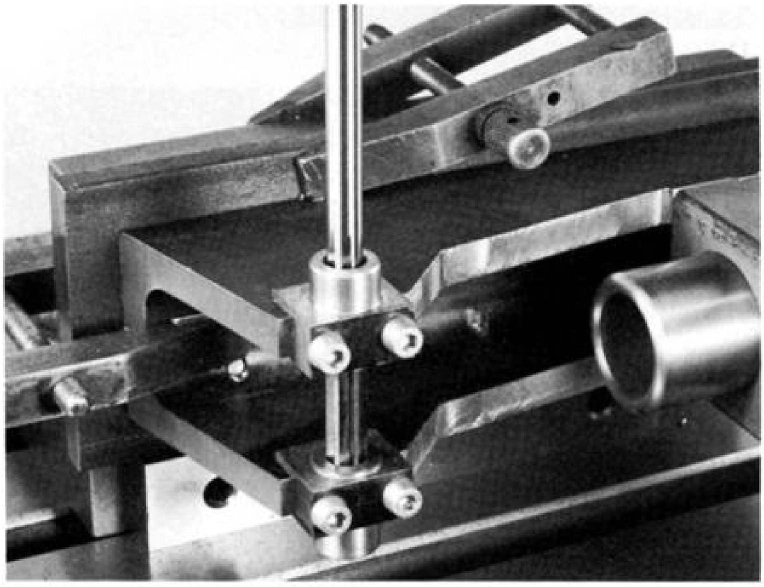
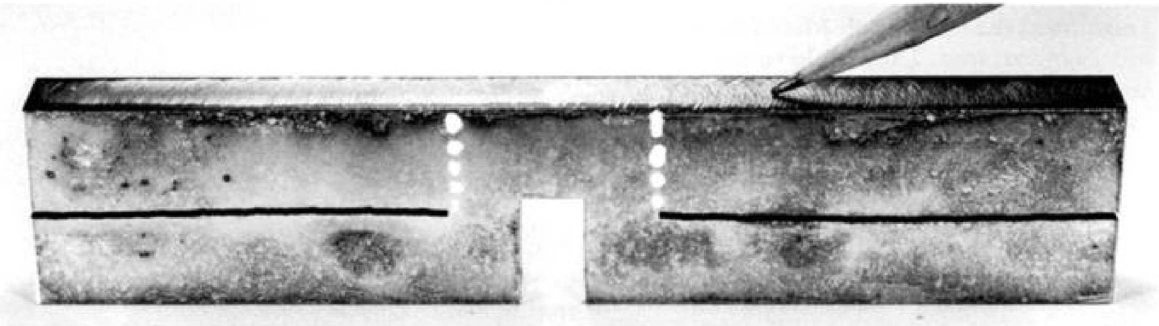


14

the bearing blocks on the motor base. Spot drill the bolt holes into the base, then tap drill and thread the holes. Bolt the bearing blocks securely in place and clamp the entire unit to an angle plate on the mill table. Run an indicator (Photo 13) along the cylinder to verify that the bearing holes will be at perfect right angles to the cylinder. Raise or lower one end of the engine base unit until a zero reading is attained.

With the aid of a wiggler or center finder, locate the mill spindle directly over the bearing block. Center drill, then drill down through both bearings with a 1/4" drill. Next, use a 11/32" drill followed by a "U" drill. Finally, ream through with a 3/8" machine or chucking reamer (Photo 14). For now, don't change the location of the mill spindle directly over the bearing holes. Position the calibrated collar on



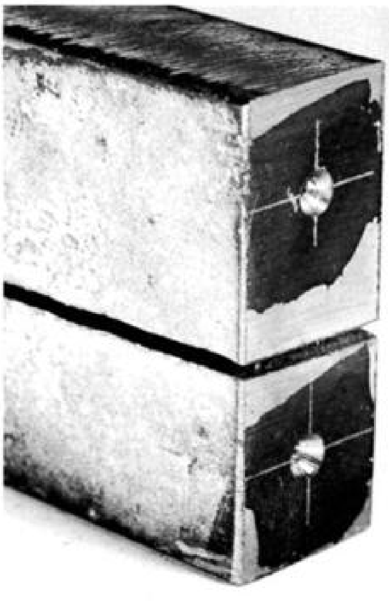
15

the cross slide to zero, then move the table the specified distance to drill and ream the hole for the cam gear shaft. Now remove the motor base from the mill and unbolt the bearing blocks. Drill and tap the setscrew hole that penetrates the cam gear shaft hole.

The Crankshaft was machined from a piece of ½ × 1¼" hot rolled steel. Use cold rolled steel if you prefer. Lay out the rough guide lines, and mill an undersize slot (Photo 15) where the crank throw will be. Now rough slit (with a hacksaw) the two shaft lines. The two dark lines in the photo are the actual cuts. Whenever a piece of steel is cut in this manner, internal strains are relieved and warping occurs.

By now the upper surface is probably curved; take a light cut in the mill to flatten it out. Use this surface to accurately lay out the center holes in each end of the piece (Photo 16). A faceplate set up as shown in Photo 17 was used for motive power to machine the con rod journal. I employed a 5/32" wide cutoff tool blade and hollow-ground a space in it to reduce chattering (Photo 18); a slow spindle speed and light cuts will help. Rough it down to about 1/32" oversize. Now expand the width of the journal to the correct size; for this task, grind two side-cutting tools – one right-hand and one left-hand (Photo 19).

The special hollow ground tool that was used to rough machine the con rod journal must now be resharpened. This time, however, hone the cutting edge with a very fine stone and slightly round off the square corners of the tool. Naturally, the two cutting edges of the tool must be held perfectly parallel with the



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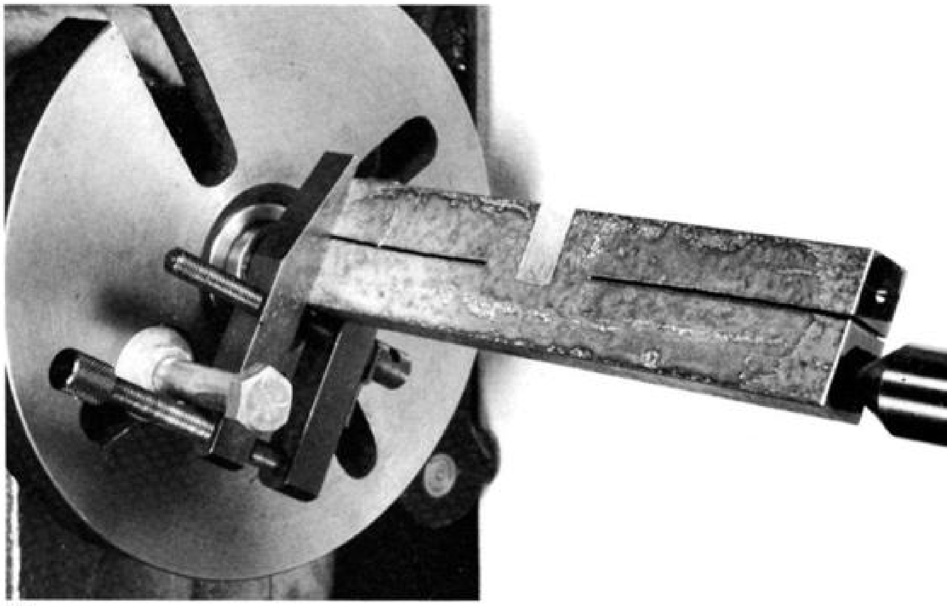

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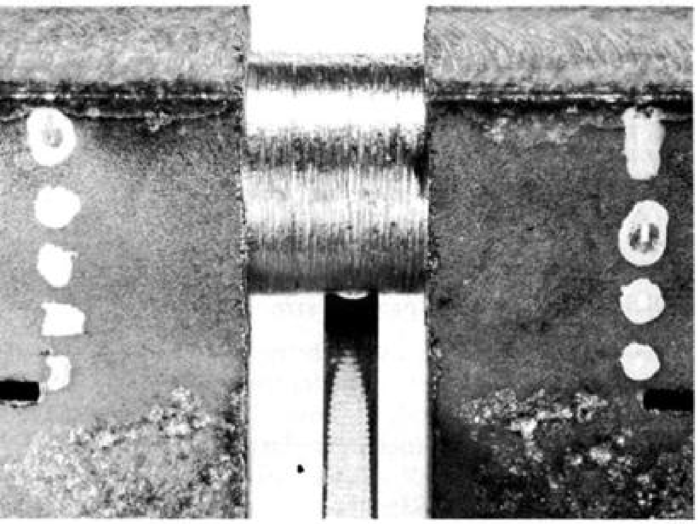

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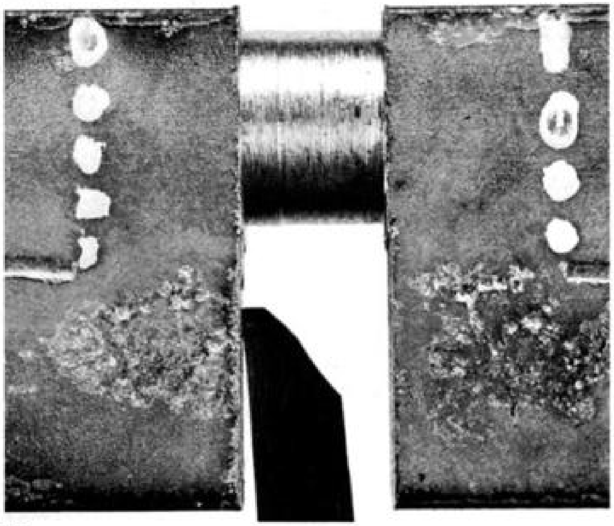

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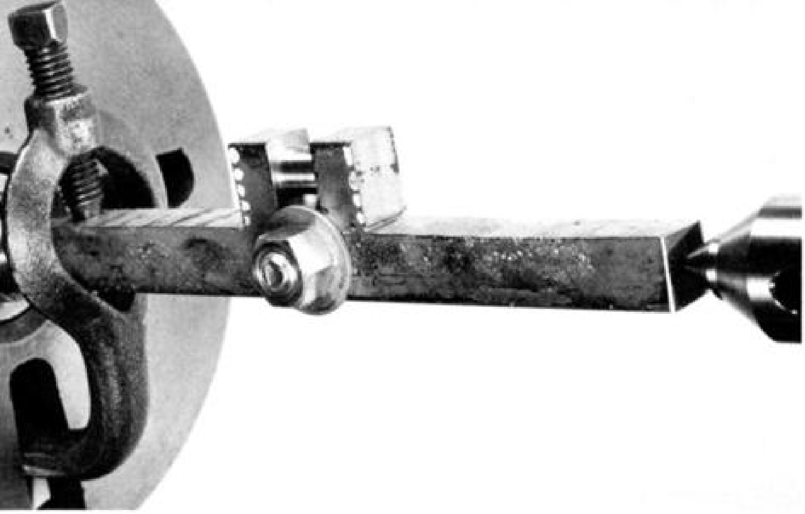
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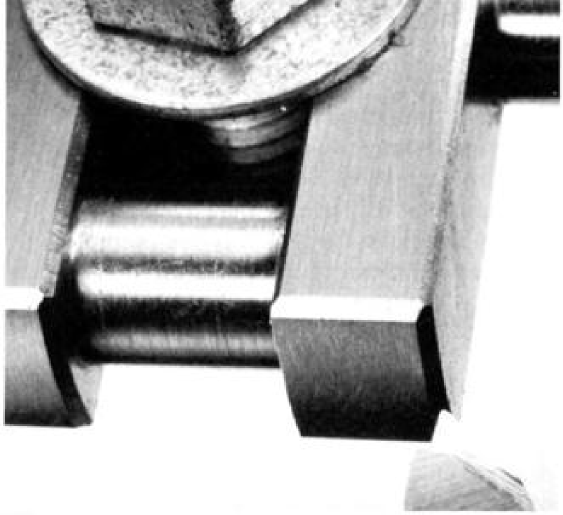
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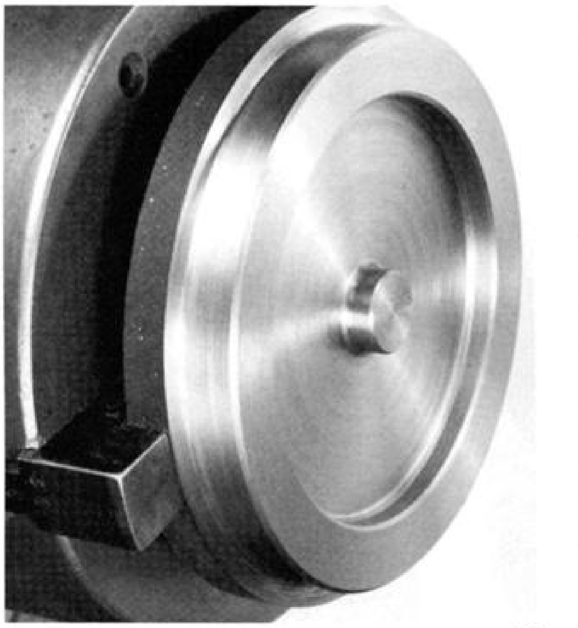
22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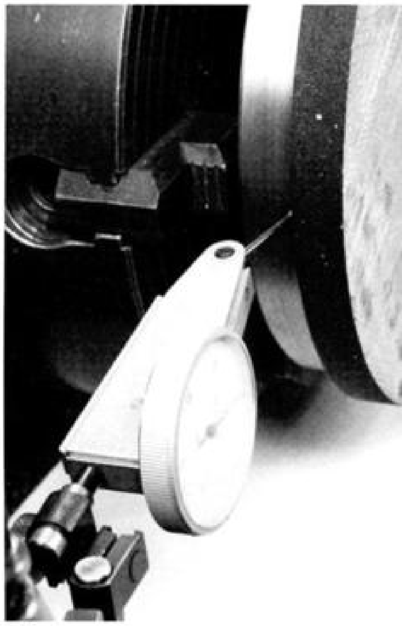
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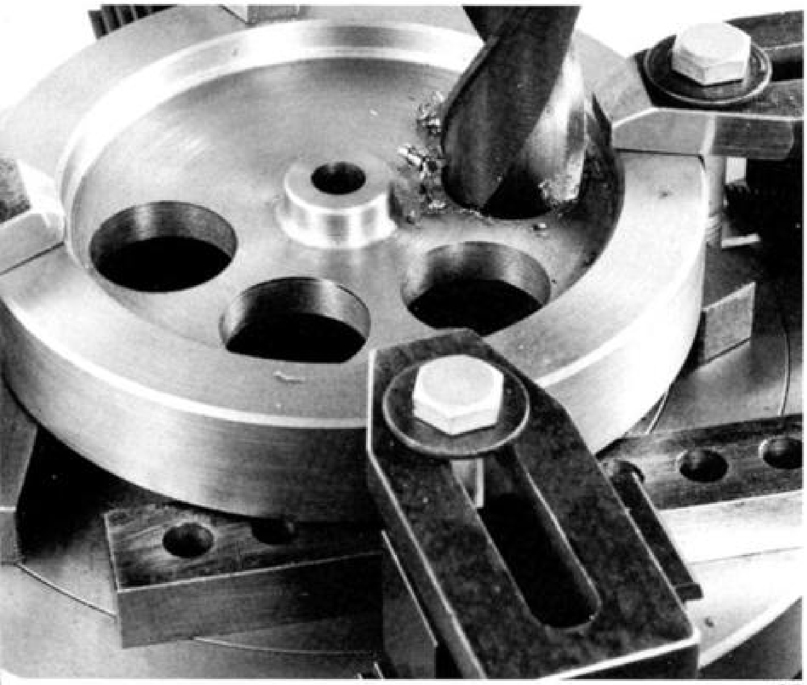
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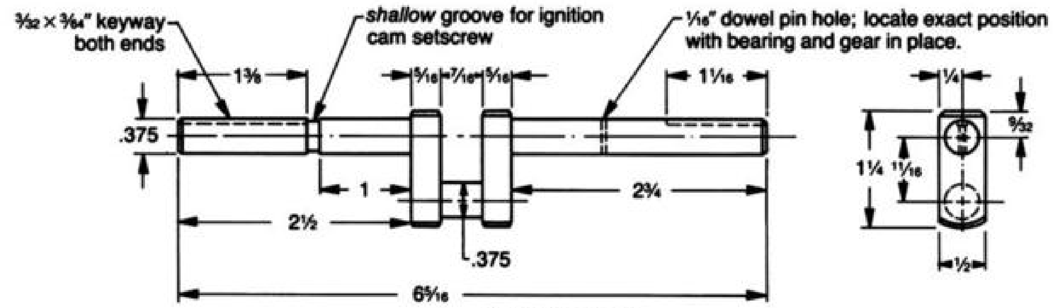
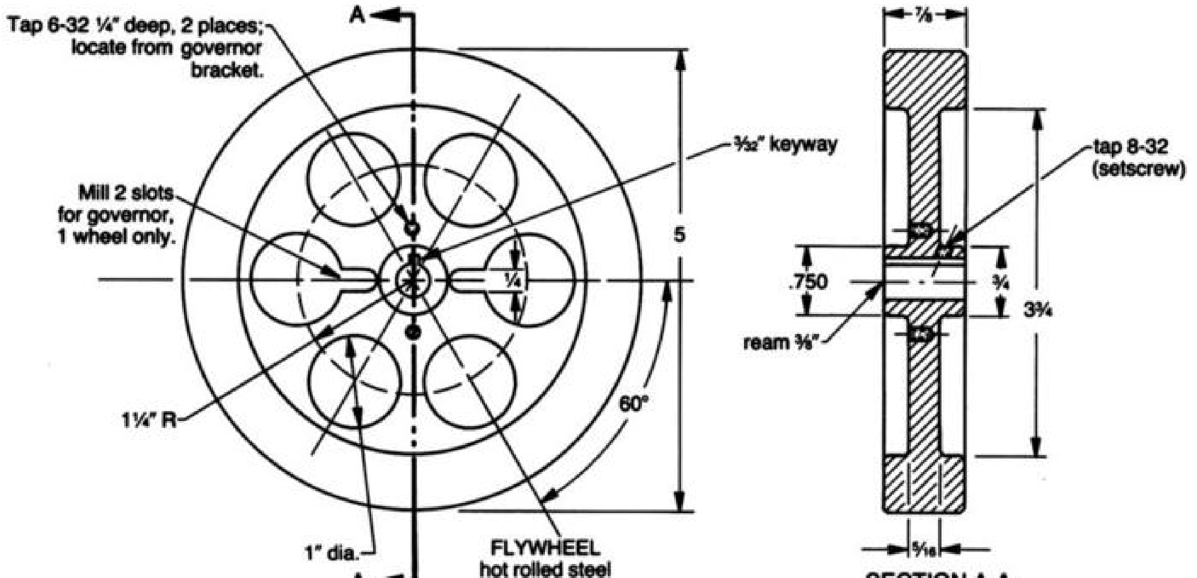
workpiece. Take very light cuts and use cutting oil. When completed, cut off the surplus portions on the crankshaft blank and prepare to machine the main shafts as in Photo 20. Clamp a 3/8" bolt *tightly* through the central slot to reduce flexing of the work. When approaching the correct diameter, use a rather pointed tool with a small radius on the tip. Hone the tool razor sharp. Take very light cuts and use a slow spindle speed together with a very slow carriage travel. Continually check for taper and for correct adjustment of the tailstock center; leave .0005" oversize and polish with fine emery paper to size.

In the milling machine, I used the tip of a 90° woodcutting router bit to chamfer the sharp edges of the crankshaft throw arms. The *ends* of the arms were machined in the lathe as in Photo 21. A 3/32" end mill was used to form the keyway slot on each end of the crankshaft.


3/32 × 3/64" keyway both ends
shallow groove for ignition cam setscrew
1/16" dowel pin hole; locate exact position with bearing and gear in place.
1 3/8
5/16
7/16
5/16
1 1/16
1/4
9/32
.375
1
2 3/4
2 1/2
.375
6 5/16
1 1/4
11/16
1/2

CRANKSHAFT
hot rolled steel


Tap 6-32 1/4" deep, 2 places; locate from governor bracket.
A
Mill 2 slots for governor, 1 wheel only.
3/32" keyway
5
1/4
1 1/4" R
60°
1" dia.
A
7/8
tap 8-32 (setscrew)
.750
3/4
3 3/4
ream 3/8"
5/16

FLYWHEEL
hot rolled steel
2 required

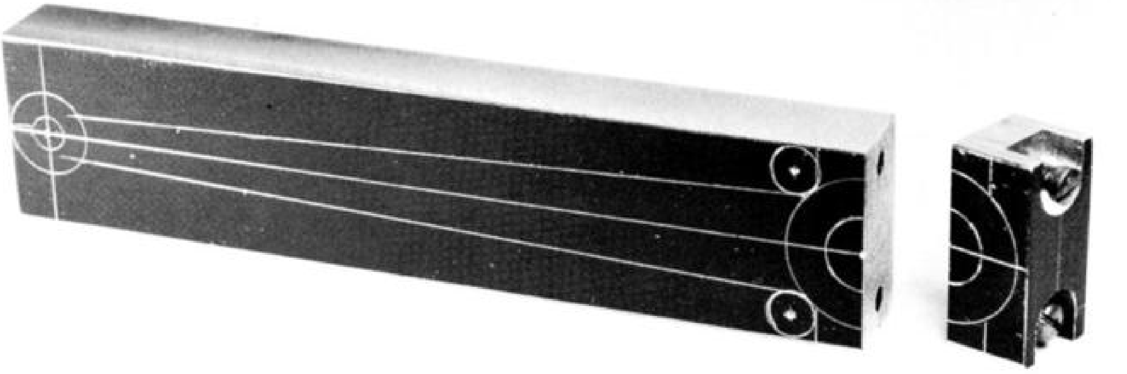
SECTION A-A

The Flywheels were machined from 5 3/8" diameter hot rolled steel. As you can see in Photo 22, I had some difficulty slicing off the pieces – this diameter was beyond the capacity of my little metal cutting band saw, but by cutting partway through and then turning the stock piece in the vise, I managed to complete the job – didn't break a blade, either! Machine as in Photo 23; cut as close to the chuck jaws as possible without hitting them. Use a four-jaw chuck for the next operation (Photo 24). Test with a dial indicator on the *side face* of the shoulder just machined and also on the wheel periphery; true up. Then machine this side identical to the other. Now drill and ream the shaft hole.

Several options are possible when making the flywheel spoke holes. I chose to center a wheel on a rotary table on the milling machine. From an initial center drill, I followed with a 1/4" drill and then with a couple of increasingly larger drills until a 1" size was reached. Location of each of the remaining holes was easily obtained by a 60° rotation of the rotary table (Photo 25). Before removing the second flywheel from the table, mill out the two governor arm slots (Photo 26).

Tempered aluminum rectangular bar stock is quite adequate for the Connecting Rod. Lay out the profile (Photo 27). Then drill and ream the two bearing holes and the two radius

26



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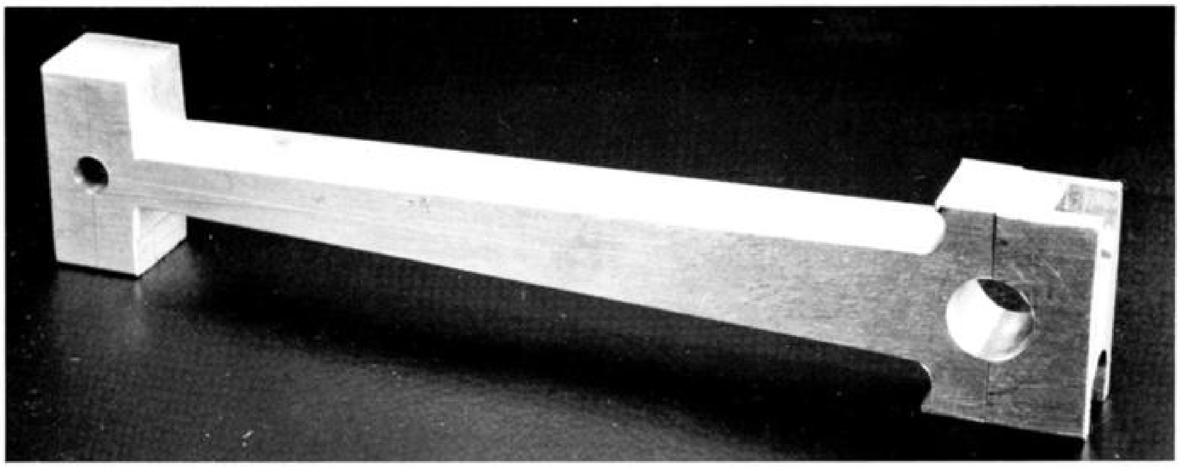
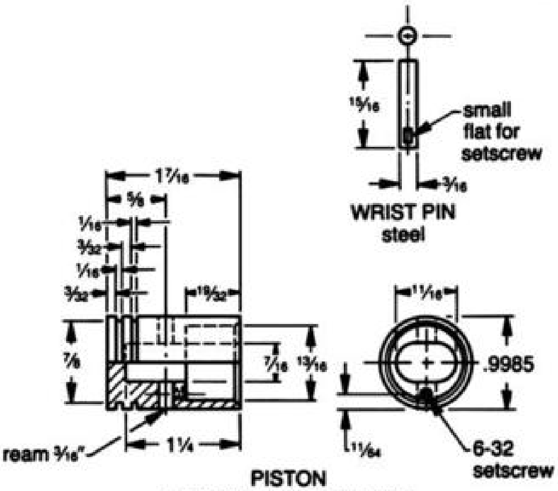


28

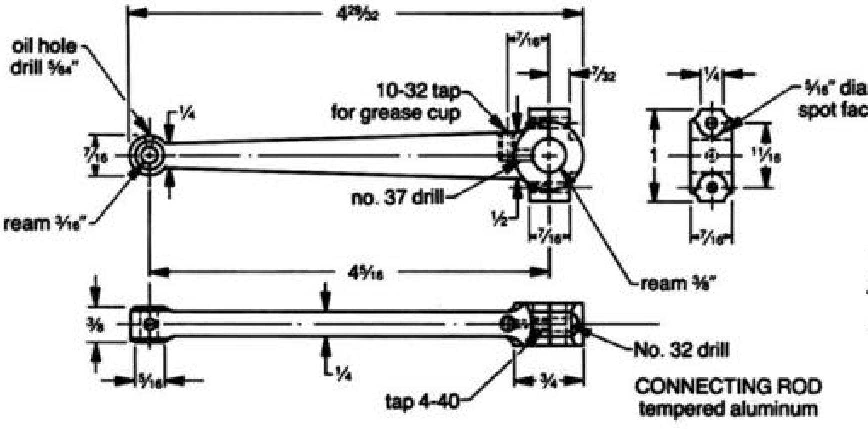
forming holes just behind the head. Mill out the tapered section (Photo 28). Then mill down the thickness (Photo 29). Center up the Wrist Pin hole over the rotary table and machine that end, including the small radius around the hole itself, as visible in Photo 30. Do the same with the large end of the con rod (Photo 31).

Aluminum was employed for the Piston material; cast iron, brass or bronze – even steel could have been used. However, these heavy metals will increase vibration when the engine is running. Photo 32 illustrates how the piston was machined, including the ring grooves; the piston is now ready to be parted from the stock piece.

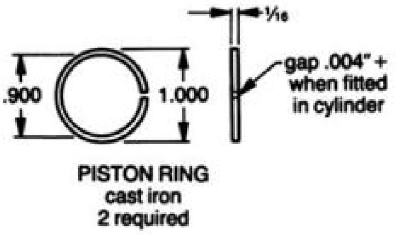

15/16
small flat for setscrew
3/16
1 7/16
5/8
1/16
3/32
1/16
3/32
19/32
7/8
7/16
13/16
ream 3/16"
1 1/4
11/16
.9985
11/64
6-32 setscrew

WRIST PIN
steel

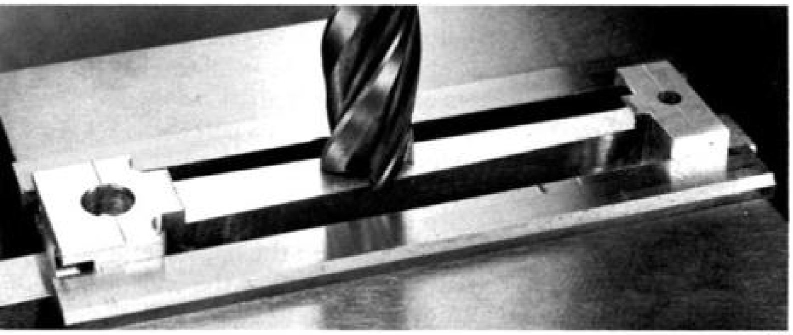
PISTON
cast or tempered aluminum


4 29/32
oil hole drill 5/64"
7/16
7/32
10-32 tap for grease cup
1/4
7/16
ream 3/16"
no. 37 drill
1/2
7/16
1/4
5/16" dia. spot face
1
11/16
7/16
4 5/16
ream 3/8"
3/8
1/4
5/16
No. 32 drill
tap 4-40
3/4

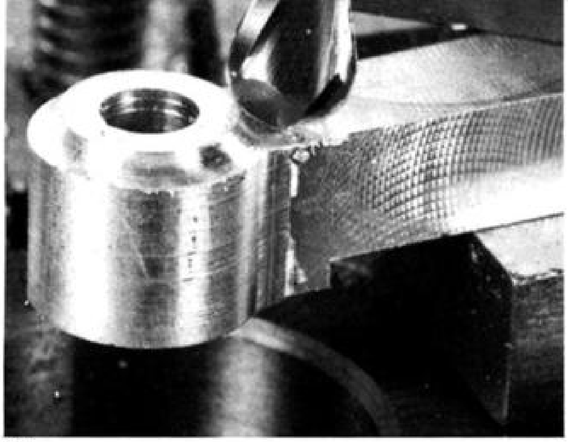
CONNECTING ROD
tempered aluminum


1/16
gap .004" + when fitted in cylinder
.900
1.000

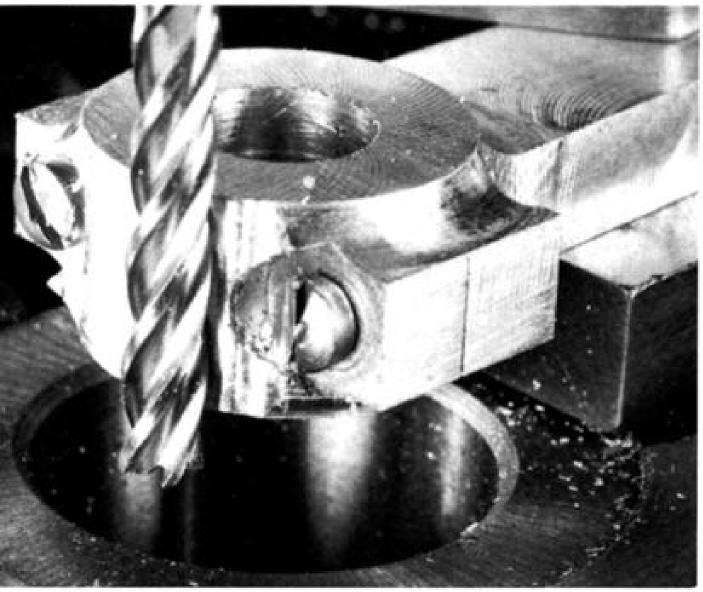
PISTON RING
cast iron
2 required



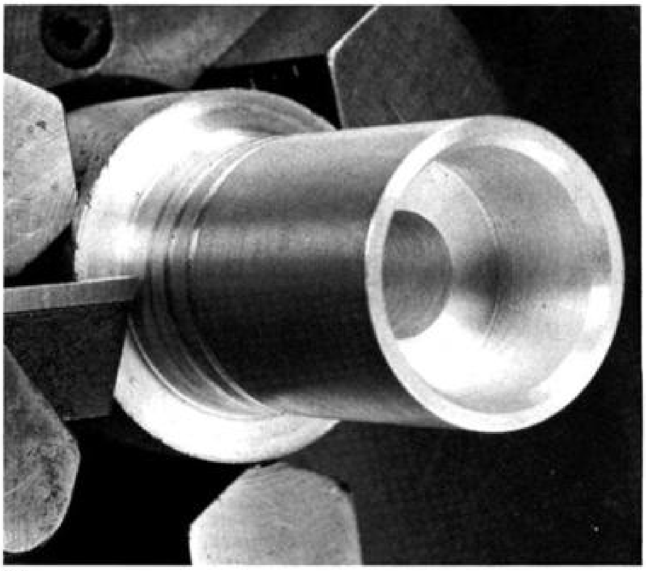
29



30



31



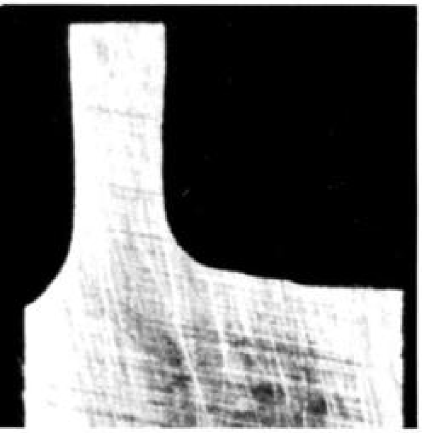
32

When grinding the Piston Ring Grooving Tool (Photo 33), the sides should taper slightly inward, thus making the tip of the tool its widest part. The tip should measure about .0005" more than the width of the Piston Rings. Depth of the ring groove is about .002" more than the thickness of the ring.

The deeper portion in the piston cavity is elongated with a 7⁄16" end mill; then the wrist pin hole is drilled and reamed. Finally, the setscrew hole is drilled and tapped.

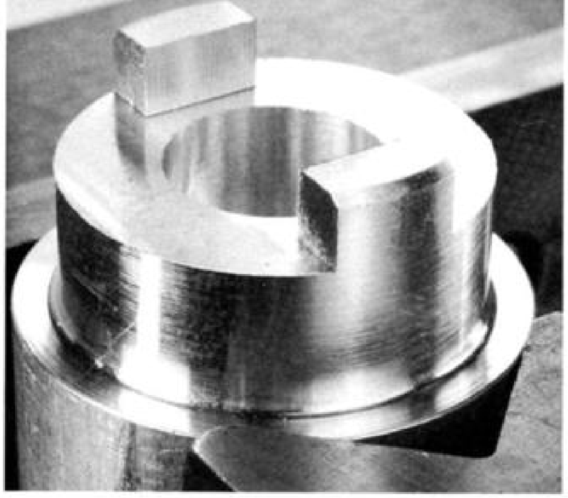
The Governor Arm Bracket can be built from almost any type of metal, but tempered aluminum is easiest to machine.

Begin by boring and turning the sleeve about 1⁄4" longer than the finished size; leave it attached to the stock piece. Now center

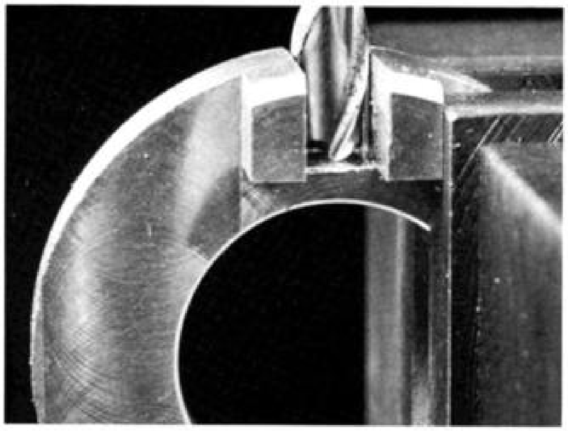


33

34



35



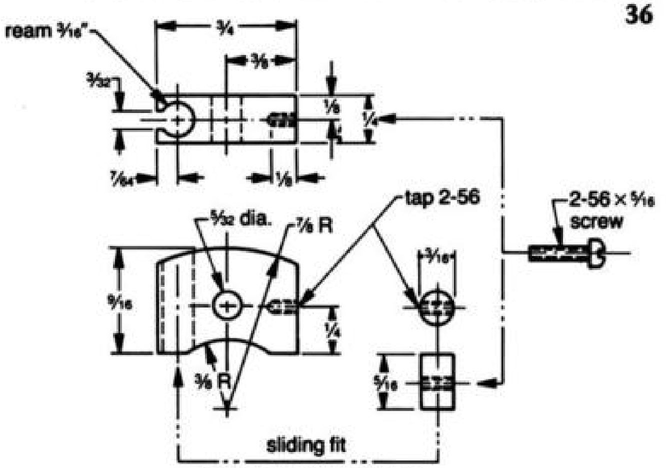
36

the sleeve *directly* beneath the milling machine spindle (Photo 34). Set the calibrated collars of the mill (both longitudinal and cross-feed) to zero. To form the two ears as in Photo 35, move the table longitudinally ⁷⁄₃₂" *plus* half the diameter of your end mill; lower the end mill the proper distance and proceed to mill one side of the ears. Return the table to the zero setting. Now advance the table in the opposite direction ⁷⁄₃₂" *plus* half the diameter of the end mill *plus* the amount of backlash in your lead screw. Mill the opposite side of the ears. Machining the gap between the ears is accomplished in the same manner by using the cross table motion. Now cut off the work from the stock piece.

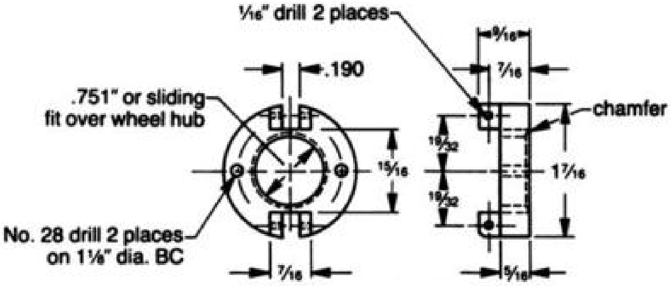
If your mill vise jaws are fairly accurate on their vertical edges, clamp the work as in Photo 36. Use an edge finder on the outer diameter of the piece. Then move the table half the diameter of the edge finder plus half the diameter of the work. Mill one slot, then reposition the bracket with the slot just milled in the lower position. Mill the second slot.

Photos 37 through 41 illustrate the method employed to machine the two steel Governor Arms. Lay out the two blanks (Photo 28) and drill the pin hole in each. Slip a pin or bolt through both pieces and clamp them in the mill vise. Mill out the contours. You'll undoubtedly have to do some hand-filing on the curved tip of each arm when fitting them into the governor spool slots.

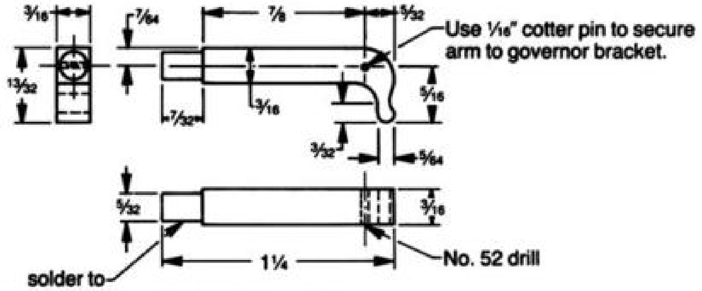
Start on the Governor Weights by machining out a steel or brass disk (Photo 42). Mill down to the edge of the hole. Remove from the vise and reposition with the surface just machined face down on a parallel. Repeat the milling operation. The two remaining segments of the workpiece are then clamped together vertically with the pointed ends uppermost; mill down as in Photo 43. Now drill the ³⁄₁₆" hole close to and parallel to one edge of each weight. Then clamp them in the mill vise and cut a ³⁄₃₂" slot


ream ³⁄₁₆"
¾
⅜
³⁄₃₂
⅛
¼
⁷⁄₆₄
⅛
⁵⁄₃₂ dia.
⅞ R
tap 2-56
2-56 × ⁵⁄₁₆ screw
³⁄₁₆
⁹⁄₁₆
¼
⅜ R
⁵⁄₁₆
sliding fit

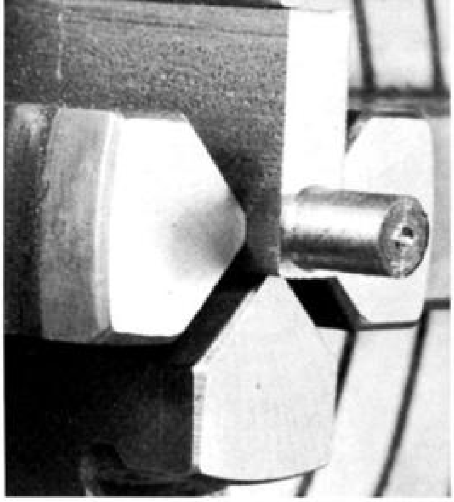
GOVERNOR WEIGHTS
steel
2 required


¹⁄₁₆" drill 2 places
.190
⁹⁄₁₆
⁷⁄₁₆
.751" or sliding fit over wheel hub
chamfer
¹⁹⁄₃₂
¹⁵⁄₁₆
1⁷⁄₁₆
¹⁹⁄₃₂
No. 28 drill 2 places on 1⅛" dia. BC
⁷⁄₁₆
⁵⁄₁₆

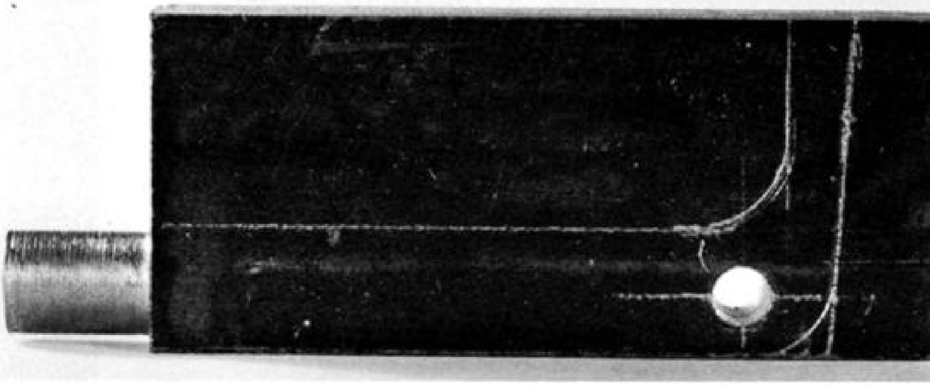
GOVERNOR BRACKET
aluminum
1 required


³⁄₁₆
⁷⁄₆₄
⅞
⁵⁄₃₂
Use ¹⁄₁₆" cotter pin to secure arm to governor bracket.
¹³⁄₃₂
⁷⁄₃₂
³⁄₁₆
⁵⁄₁₆
³⁄₃₂
⁵⁄₆₄
⁵⁄₃₂
³⁄₁₆
1¼
No. 52 drill
solder to governor weight

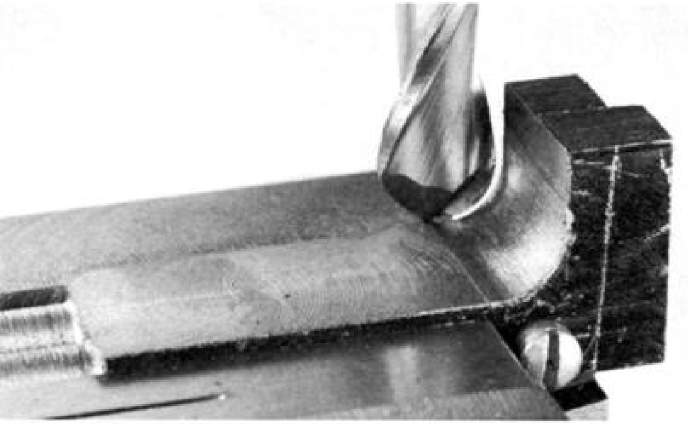
GOVERNOR ARMS
steel
2 required



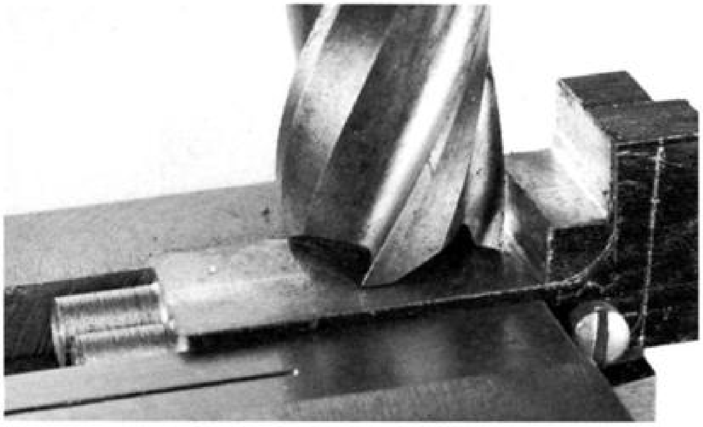
37



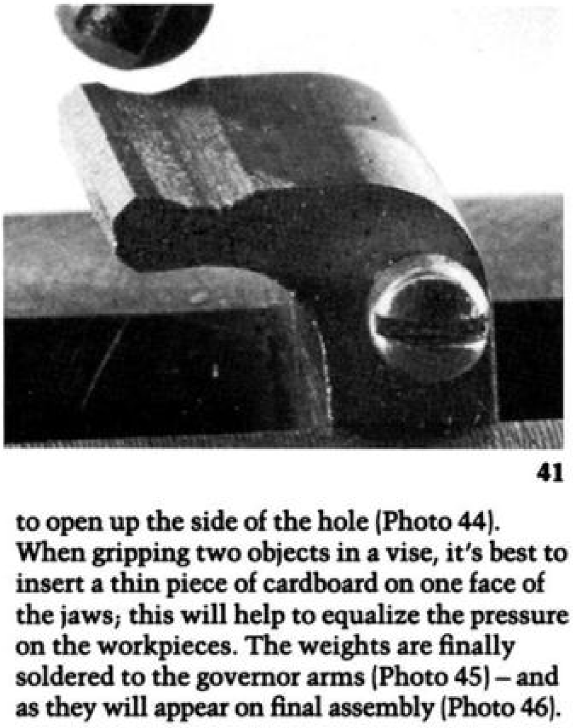
38



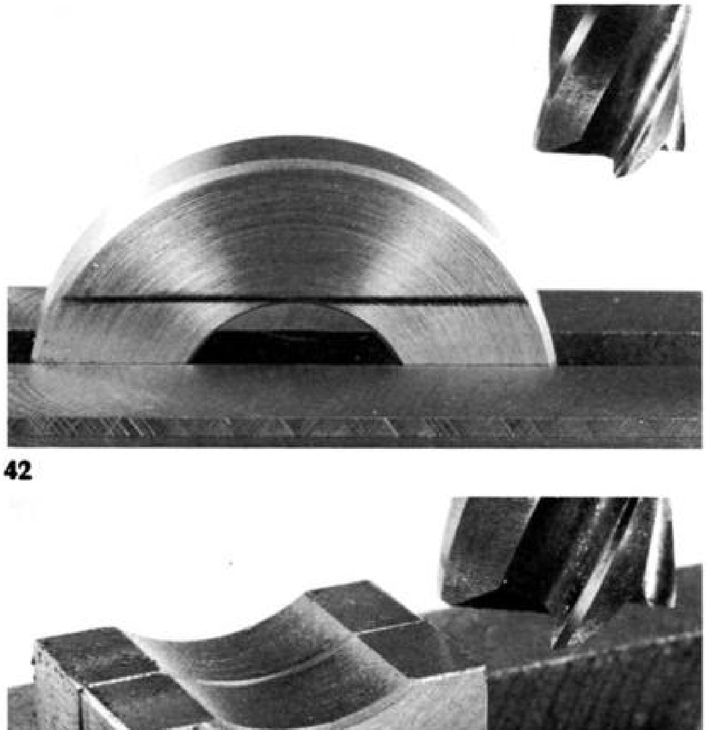
39



40



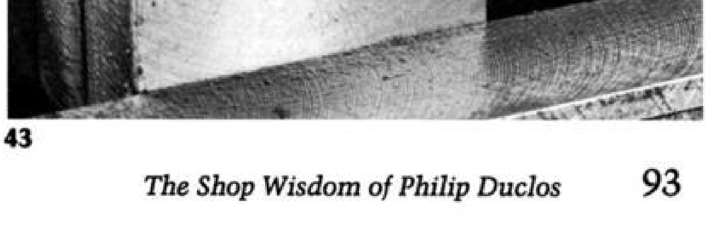
41



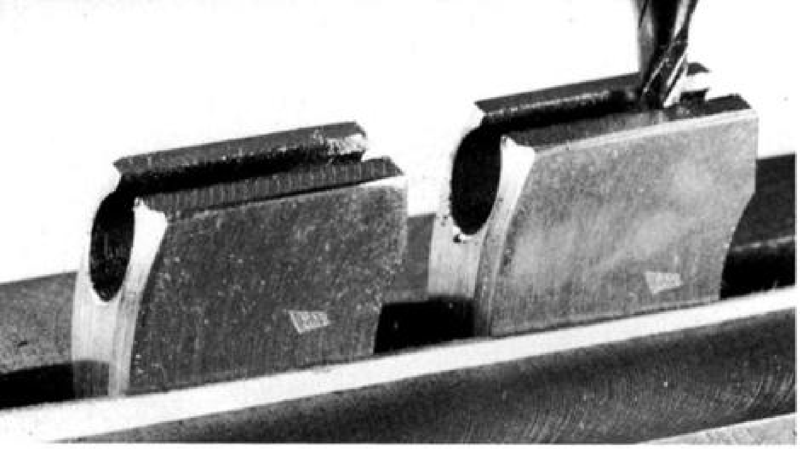
42

to open up the side of the hole (Photo 44). When gripping two objects in a vise, it's best to insert a thin piece of cardboard on one face of the jaws; this will help to equalize the pressure on the workpieces. The weights are finally soldered to the governor arms (Photo 45) – and as they will appear on final assembly (Photo 46).

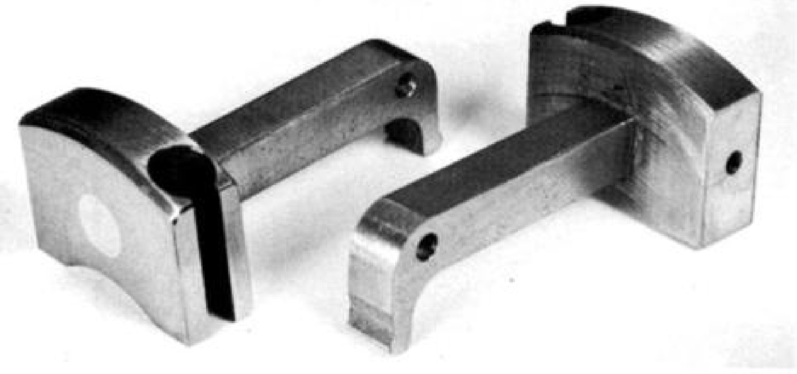
There are two options for obtaining the Timing Gears: machine them yourself or purchase them from Coles' Power Models. They sell the same size gears (rather expensive) for their small hit and miss engine. Usually



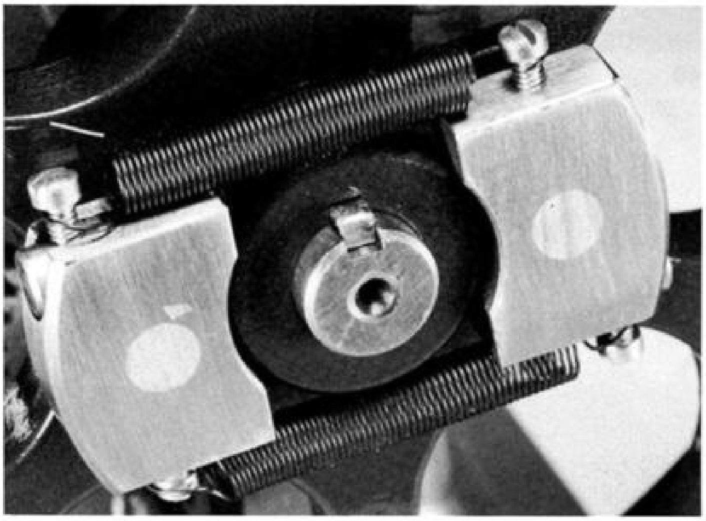
43



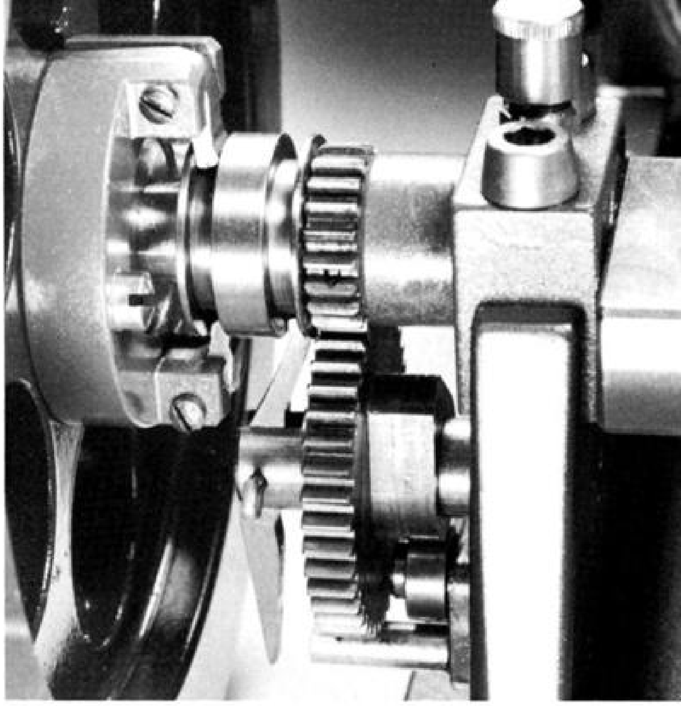
44



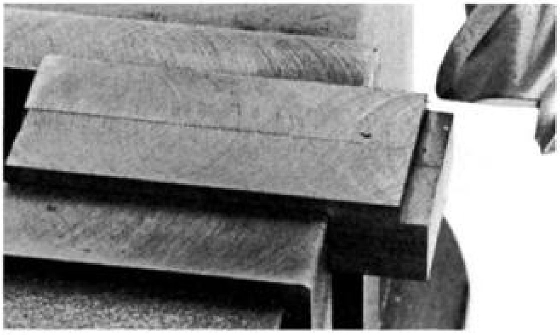
45



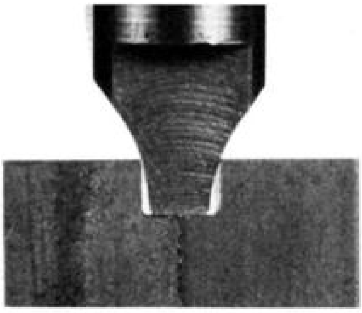
46



47



48



49

the cam is built separately and then bolted or soldered to one side of the large gear. Not wanting to spend at least $50 for a pair of involute gear cutters, I decided to fly cut my own gears. At the same time, why not machine the cam as an integral part of the large gear, as visible in Photo 47?

If you have one of those popular "spin-index" horizontal milling fixtures, you're in business to fly cut your own gears; in fact, most any type fixture that will divide a circle into 20 and 40 divisions will work. True, the gear teeth formed by this unorthodox fly cutting method will certainly *not* have a true involute tooth form – but even the best gears in the world are not perfect, so let's bend the rules a little!

Start by machining a simple gage to accurately measure the fly cutter tool bit (Photo 48).

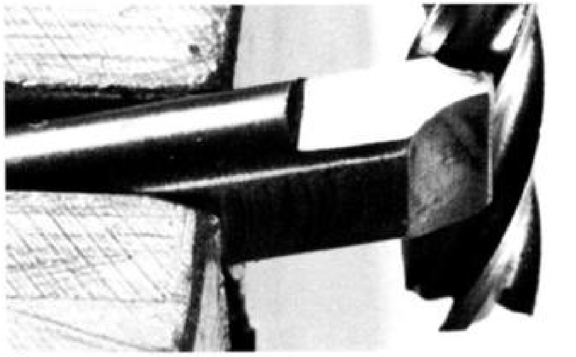
Clamp two pieces of 3⁄16" square cold rolled steel in the mill vise. Take a light cut on the top surface to clean it up; set the vertical travel calibrated collar of the mill to zero. Now lower the end mill to clean up the exposed end of the two pieces. Set the longitudinal calibrated collar of the table to zero. Move the end mill to one side of the work; elevate the end mill up to the original zero setting. Now lower it .0245". With the table positioned at its previously set zero mark, advance the table .036". Now mill the step on the gage. Carefully remove any burrs – the outer end of the step should be sharp and clean. Double check the width and depth of the step with a depth mike.

Remove the work from the vise and carefully clamp the two pieces together to form the channel in the gage (Photo 49). This photo also indicates how the gage is used when checking the form of the fly cutter tool bit. The tool must touch both the depth in the gage as well as its two sharp outer edges.

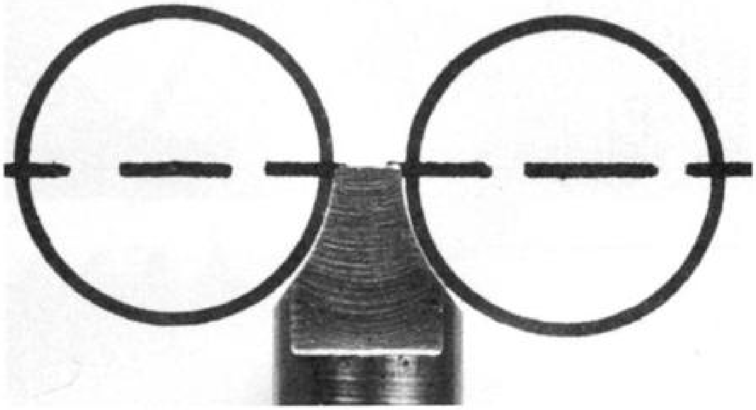
A piece of 3/16 × 1" drill rod is used for the fly cutter tool bit. Mount the drill rod horizontally in the mill vise. Leave enough of it exposed above the jaws to machine a flat surface about 7/64" wide along its entire length. Now reposition the work horizontally at the right-hand side of the vise. The flat just milled should be facing toward you and in a vertical position against the jaw. Allow the end of the rod to extend about 5/16" beyond the vise. Now machine a flat on the upper extended portion at least 1/8" wide and about 1/4" long. Loosen the vise jaw and tilt the work up 15°.

Now you must install a *sharp* 5/32" diameter end mill to do the cutting (Photo 50). Lower the end mill enough to face off the outer end of the drill rod to this new angle. Run the cutter back and forth until it ceases to cut. Set the calibrated longitudinal collar to zero. The side of the end mill will also be employed to form the radius on each side of the tool. Examine Photo 51. The two circles represent the diameter of the end mill. One side of the work is milled and then the end mill is lifted over the workpiece and lowered on the other side *without* changing the longitudinal table setting – thus the two radii on the workpiece will be in the same plane.

So, with the longitudinal table setting still at zero, use the cross slide to position the end mill so that it will clear the side of the workpiece nearest you. Advance the table longitudinally one half the actual diameter of the end mill plus .002". Lock the longitudinal travel of the table. With the spindle rotating at a rather slow speed, use the cross slide to bring the cutter to just touch the side of the work. Set the cross slide collar to zero, then slowly feed into the work about .055". As you reach this setting, raise and lower the end mill somewhat while cutting to impart a smoother finish to the work. Stop the machine. Raise the end mill above the work, move it far enough to clear the opposite side and lower it.



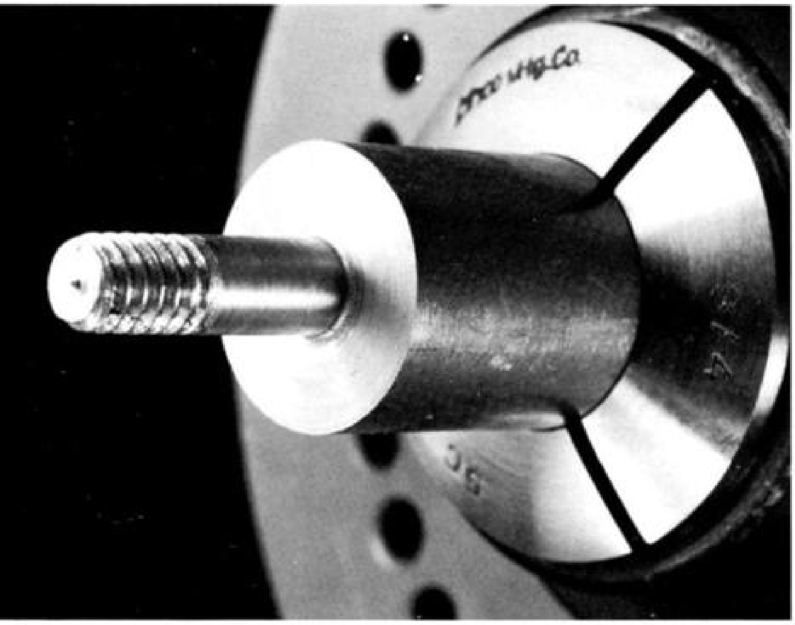
50



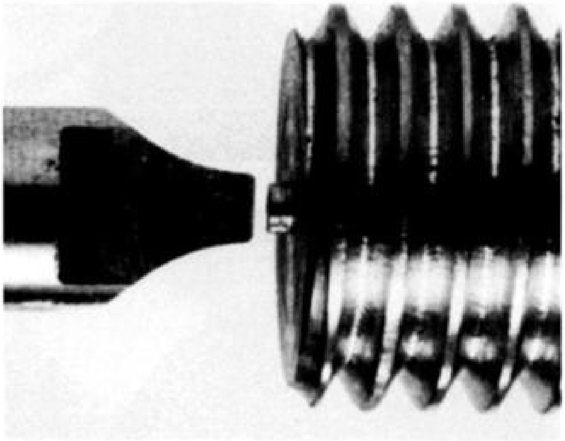
51

52

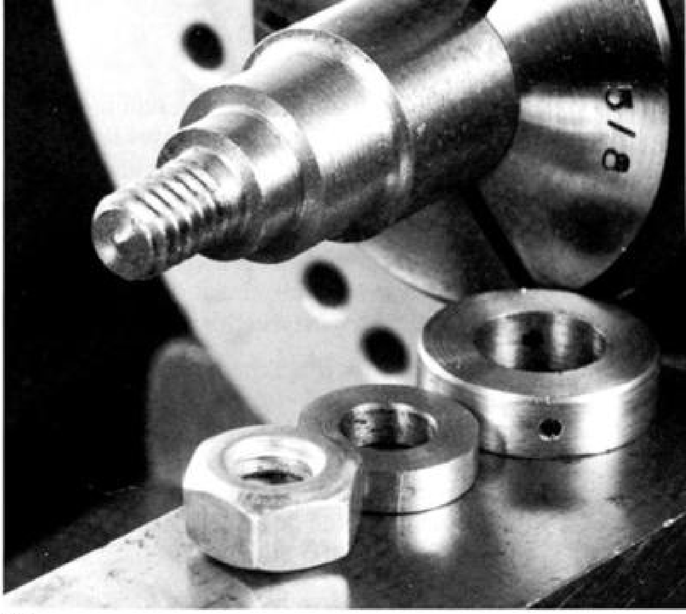
Now it's a matter of gradually milling the second radius. Continually check, using the width and depth gage until it will fit properly over the end of the work. If you accidently machine the tool too narrow, then shave off 1/64" or so from the very tip of the tool, reset the table calibrated collar to the new zero setting



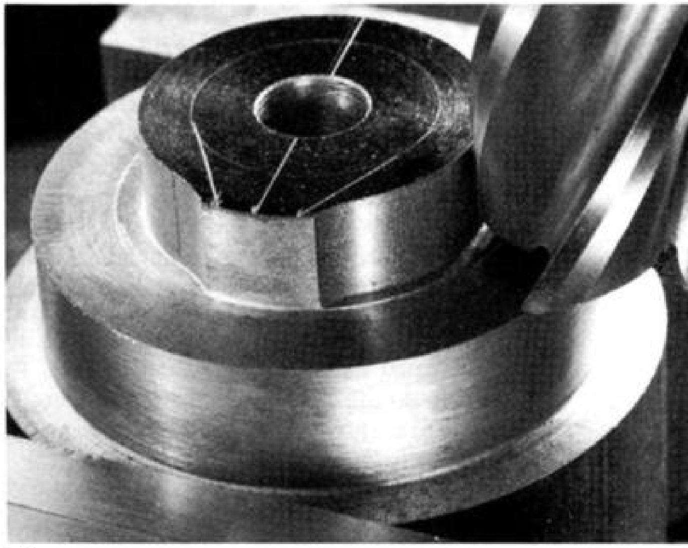
53



54



55



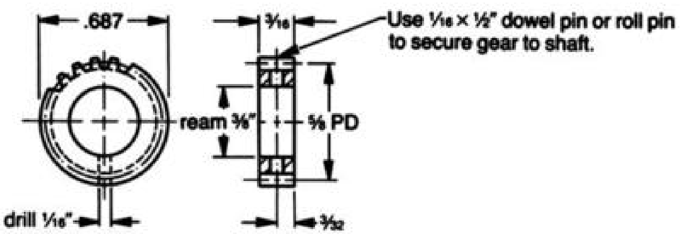
56

and follow the remainder of the entire procedure as before. The completed configuration on the end of the tool does *not* have to be perfectly in line with the center line of the 3/16" drill rod bit. Harden and temper the end of the tool to a medium straw color. Sharpen the flat top surface of the tool. The cutting edge should be sharp and clean.

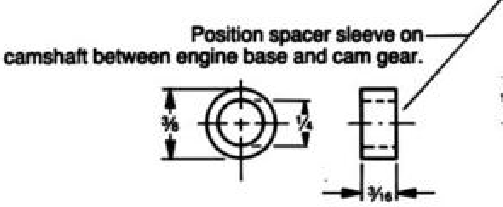
The fly cutter bar is made from a 3/4" diameter by 4" length of steel (Photo 52). Note that the 3/16" cross hole for the cutter is offset 1/16" below the center line of the shaft, as is the 10-32 setscrew hole.

In order to hold the gear blanks during the machining process, it's necessary to build two simple stub arbors. Photo 53 illustrates the arbor for the large gear. Chuck up a 3" piece of 3/4" steel rod. Machine down to .250" for a distance of 3/4". Run the 1/4-20 threads to a length of about 5/16". Machine a small center protrusion or point on the very end of the arbor (Photo 54); this will aid in setting the fly cutter tool on center, later on.

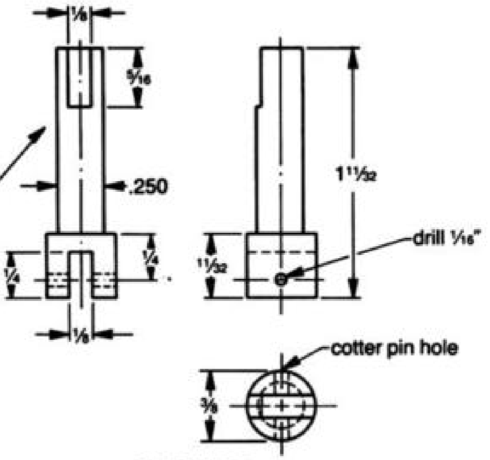
A piece of 5/8" rod was employed for the small gear arbor. Thread the outer end 1/4-20 for a length of about 3/8" (Photo 55). The adjacent diameter is .375" by 5/32" long. The third diameter is about 1/2" by 3/8" long and is merely clearance so the fly cutter won't plow into it. Visible in the photo are the small gear blank, thick washer, and the nut to hold everything securely on the arbor. Machine out *both* gear blanks *before* fly cutting the gear teeth. Begin with the large gear blank. Cast iron was used for this one, although it could be machined from aluminum, brass, or steel. Chuck up the material in the lathe and step cut it for the major diameter of the cam section, and next to this the major diameter of the gear blank.


.687
3/16
Use 1/16 × 1/2" dowel pin or roll pin to secure gear to shaft.
ream 3/8"
5/8 PD
drill 1/16"
3/32

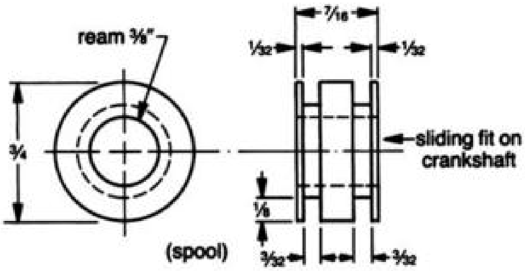
CRANKSHAFT GEAR
steel
32 P 20 teeth
1 required


Position spacer sleeve on camshaft between engine base and cam gear.
3/8
1/4
3/16

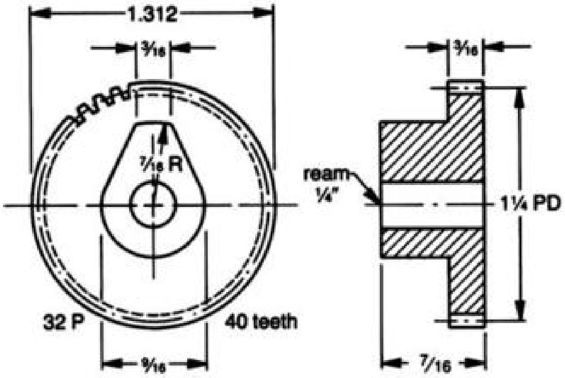
SPACER SLEEVE
steel
1 required


1/8
5/16
.250
1 11/32
1/4
1/4
1/8
11/32
drill 1/16"
cotter pin hole
3/8

CAMSHAFT
steel
1 required


ream 3/8"
7/16
1/32
1/32
sliding fit on crankshaft
3/4
1/8
(spool)
3/32
3/32

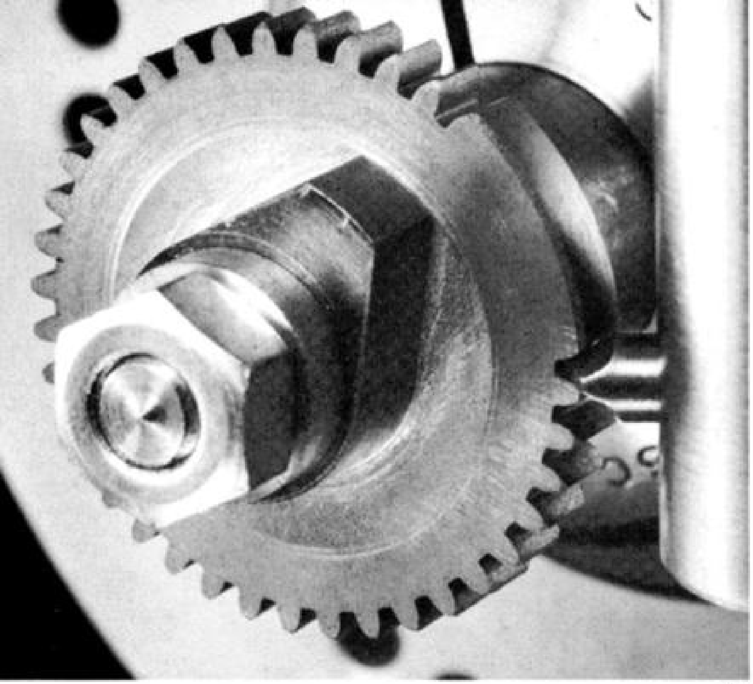
GOVERNOR SLEEVE
steel
1 required


1.312
3/16
7/16 R
ream 1/4"
1 1/4 PD
32 P
40 teeth
9/16
3/16
7/16

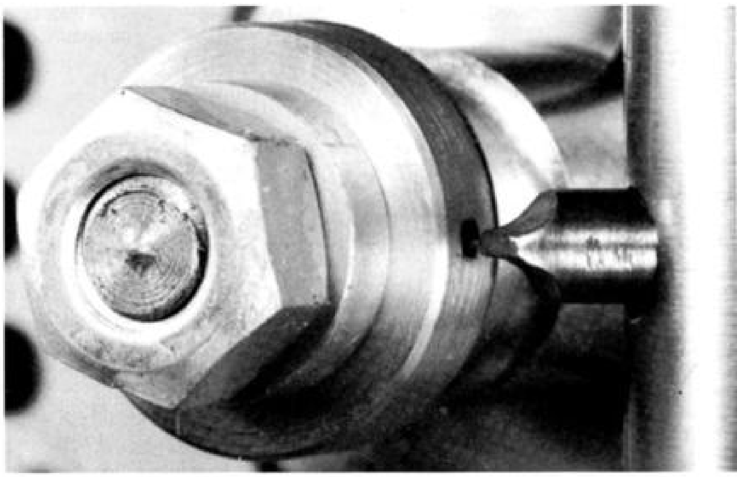
CAM GEAR
cast iron, steel, brass or aluminum
1 required

Machine this portion for a length of at least ⅜" (to allow for cutoff later on). Now drill and ream out the hole to .250". Remove from chuck. Scribe the guide lines on the blank for the cam configuration. Now mount the blank unit vertically in a small vise (Photo 56). Position the vise on a rotary table and accurately center the work true to the table center; use a dial indicator. Install a sturdy end mill and finish the cam as close to the layout lines as possible. Remove from the mill and cut off the gear blank from the stock piece. Follow by machining the gear blank portion to the proper thickness.

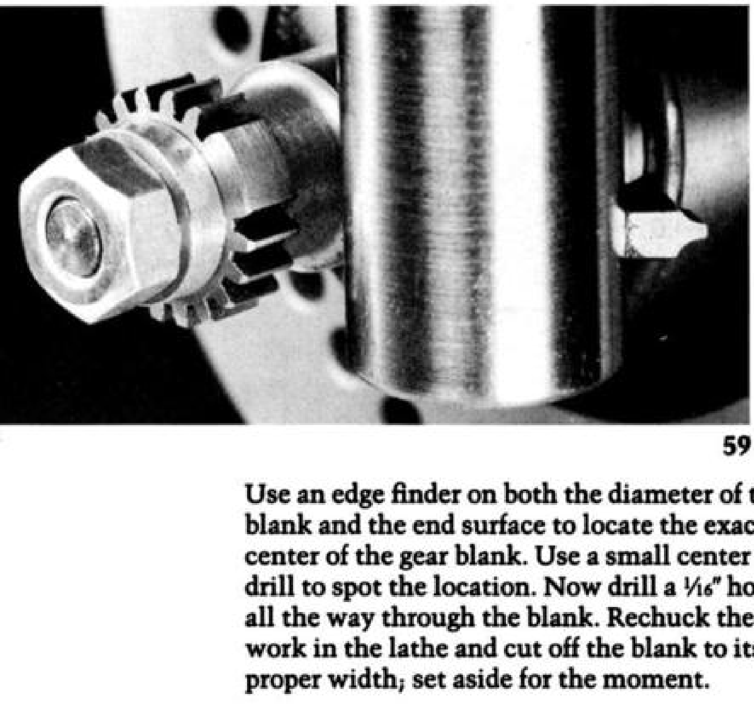
The small gear blank is turned from a ¾" diameter steel rod. Machine the OD to the proper size and about 3⁄16" longer than needed. Then drill and ream the ⅜" hole a little deeper than the thickness of the finished gear. Mount the stock piece horizontally in the mill vise.



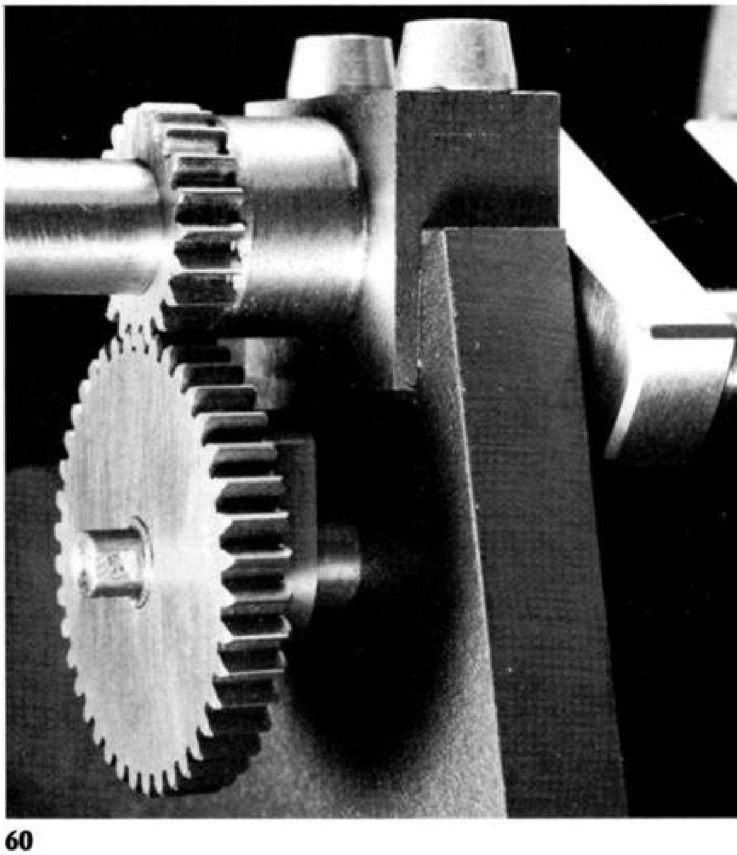
57



58



59



60

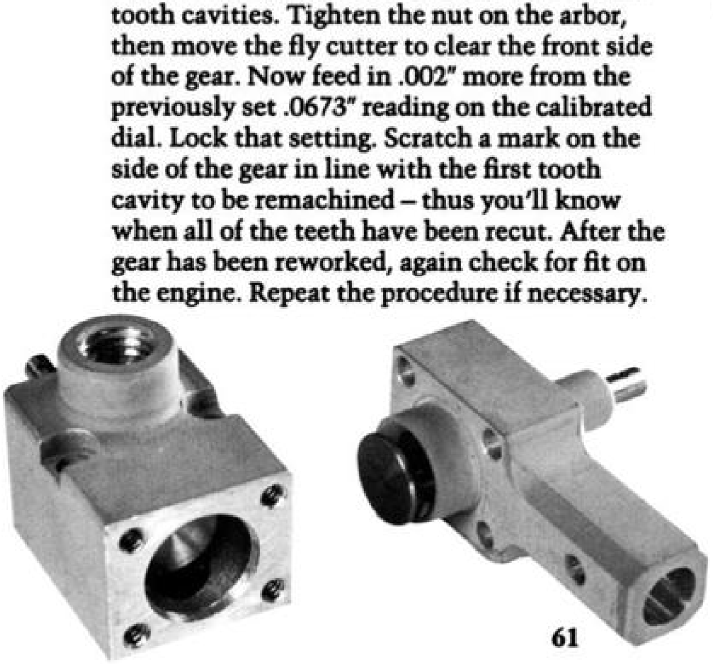
Use an edge finder on both the diameter of the blank and the end surface to locate the exact center of the gear blank. Use a small center drill to spot the location. Now drill a 1/16" hole all the way through the blank. Rechuck the work in the lathe and cut off the blank to its proper width; set aside for the moment.

Mount the large gear blank in the indexing fixture (Photo 57). Line up the center of the fly cutter tool bit with the center of the arbor shaft (refer back to Photo 54). Lock the spindle height adjustment. As there are 40 divisions or teeth in the gear, you must index or rotate the index spindle exactly 9° to form each tooth. Use a fairly slow spindle speed for the fly cutter. Advance the revolving fly cutter in line with the periphery of the gear blank until it just scratches the outer diameter. Set the appropriate table calibrated collar to zero. Now move the fly cutter towards the outer end of the gear arbor to completely clear it from the workpiece. This will assure the use of "push" milling; *never* use the "climb" motion when fly cutting a gear. The depth of each tooth will be .0673". Advance the table that amount from the previously set zero reading. Lock the table in that direction as well as the spindle height adjustment on the quill. The revolving fly cutter is advanced *slowly* so that it doesn't bang into the work. Continue a slow feed as the cutter passes through the blank.

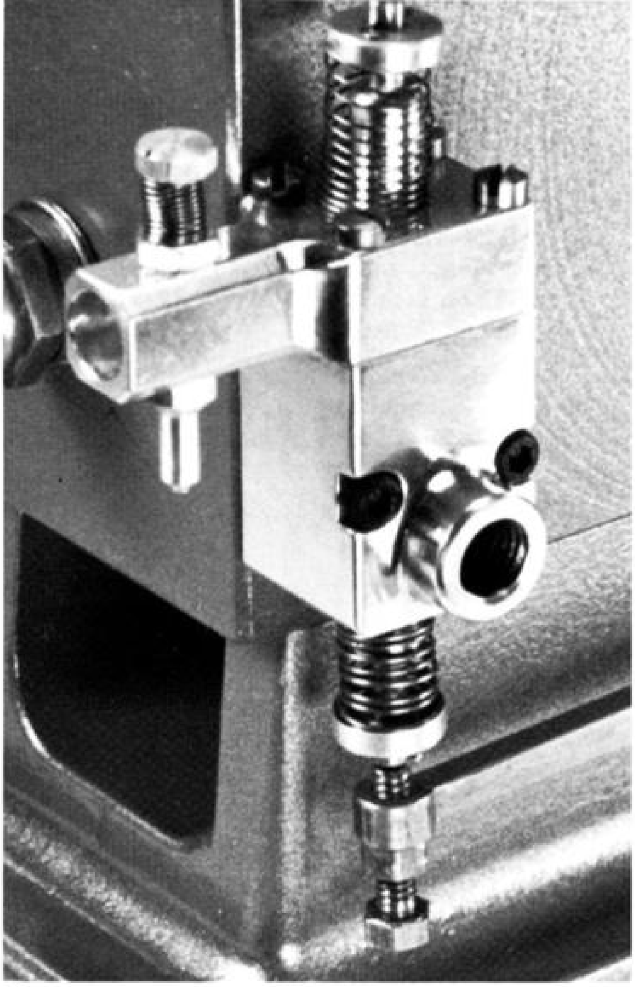
Now reverse the table motion to bring the cutter back in front enough to clear the work. Stop the mill spindle. Index the fixture 9°, start the mill and proceed to cut the next tooth.

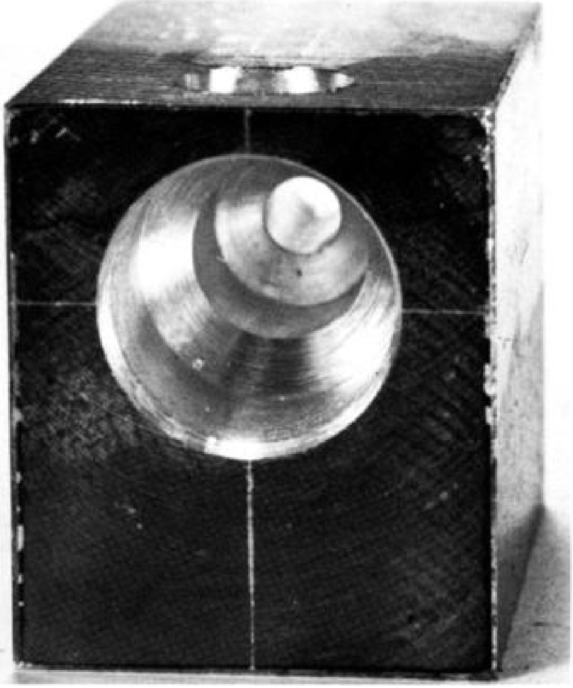
After finishing all the teeth, remove the stub arbor from the index fixture and install the one for the small gear blank as shown in Photo 58. Check your index fixture; it should be set to begin a division of 20 equal spaces, or 18° per division. Adjust the gear blank until the 1/16" hole in its circumference is lined up with the center of the fly cutter tool. Then tighten the holding nut.

From now on the procedure is identical to cutting the large gear. Use cutting oil on the steel gear blank. Photo 59 shows the gear nearing completion. When finished, remove the gear from its arbor, but *do not* change anything else on the setup. Since this is a "hit 'n miss" method of machining gears, it's necessary to double check that the two gears won't bind when mounted on the engine. Slip a temporary piece of 1/4" rod into the cam shaft hole in the side of the engine frame (Photo 60). Slide the large gear onto it. Now mount the small gear onto the crankshaft above the large gear – they should revolve together without binding. A small amount of backlash or play between the teeth is ideal. If binding occurs, remove the small gear and remount it loosely on the index arbor in the milling machine. Swing the fly cutter tool around and position it approximately in the center of one of the gear tooth cavities. Tighten the nut on the arbor, then move the fly cutter to clear the front side of the gear. Now feed in .002" more from the previously set .0673" reading on the calibrated dial. Lock that setting. Scratch a mark on the side of the gear in line with the first tooth cavity to be remachined – thus you'll know when all of the teeth have been recut. After the gear has been reworked, again check for fit on the engine. Repeat the procedure if necessary.


61

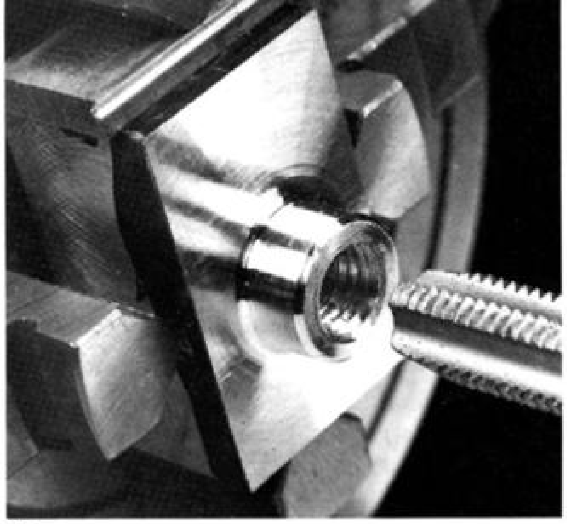
Begin work on the Intake and Exhaust units (Photo 61). Both units were machined from blocks of tempered aluminum. Brass, cast iron, or steel could also be employed. Photo 62 shows the completed valve unit bolted to the cylinder block. Lay out the center lines for what will be the exhaust valve chamber and the exhaust port holes. In a four-jaw chuck center the cross lines for the valve chamber, carefully center drill, and then slowly and gently run a No. 31 drill all the way through


62

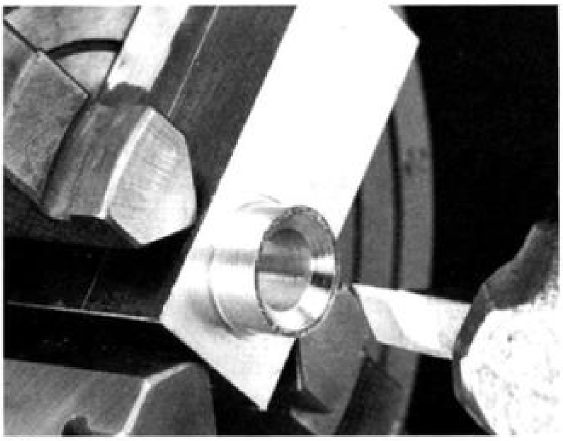

63

the piece – we don't want a wobbly hole! Then drill out portions of the hole to the specified sizes. Be careful to go only the proper depth with each drill. Now ream what's left of the original No. 31 hole to .125". Use a small boring bar to machine the 45° angle on the valve seat inside. The finished valve seat is visible in Photo 63.

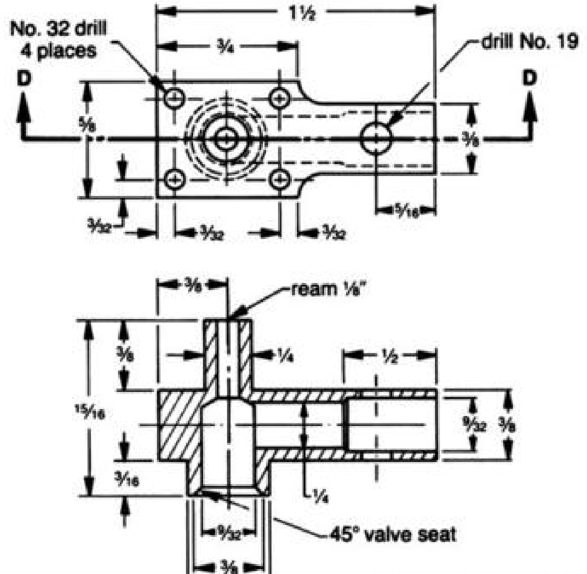
Note the port hole on the upper surface of the block; this hole will mate with the dual purpose intake-exhaust hole located on the



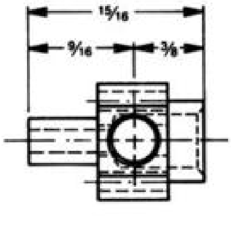
64

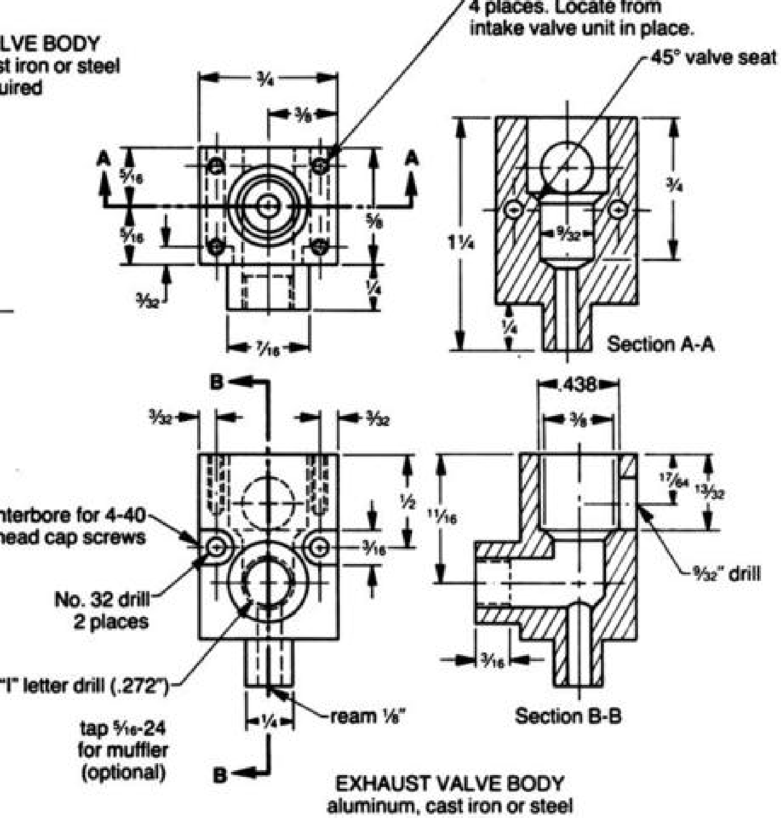


65

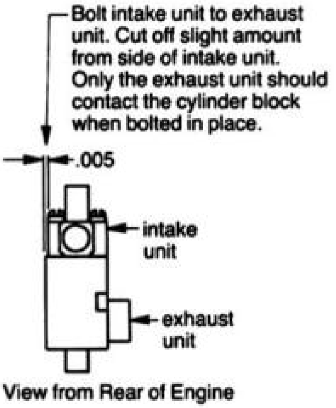

No. 32 drill
4 places
1½
¾
drill No. 19
D
D
⅝
⅜
5/16
3/32
3/32
3/32
⅜
ream ⅛"
⅜
¼
½
15/16
9/32
⅜
3/16
¼
9/32
45° valve seat
⅜
.437
Section D-D

INTAKE VALVE BODY
aluminum, cast iron or steel
1 required

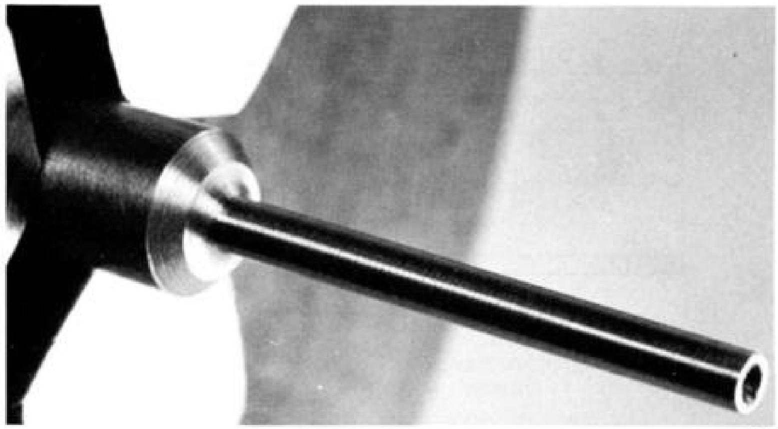



Tap 4-40 × 5/16" deep,
4 places. Locate from
intake valve unit in place.
45° valve seat
¾
⅜
A
A
5/16
5/16
⅝
3/32
¼
7/16
1¼
¾
9/32
¼
Section A-A
B
B
3/32
3/32
½
11/16
3/16
counterbore for 4-40
socket head cap screws
No. 32 drill
2 places
"I" letter drill (.272")
tap 5/16-24
for muffler
(optional)
¼
ream ⅛"
.438
⅜
17/64
13/32
9/32" drill
3/16
Section B-B

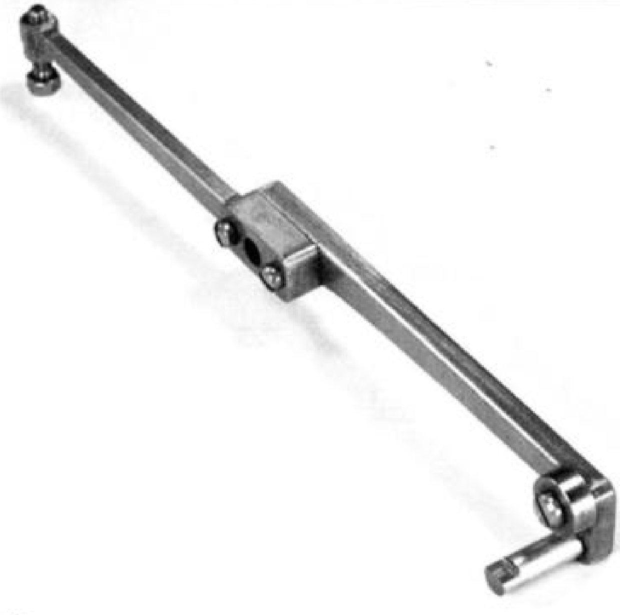
EXHAUST VALVE BODY
aluminum, cast iron or steel
1 required


Bolt intake unit to exhaust
unit. Cut off slight amount
from side of intake unit.
Only the exhaust unit should
contact the cylinder block
when bolted in place.
.005
intake
unit
exhaust
unit

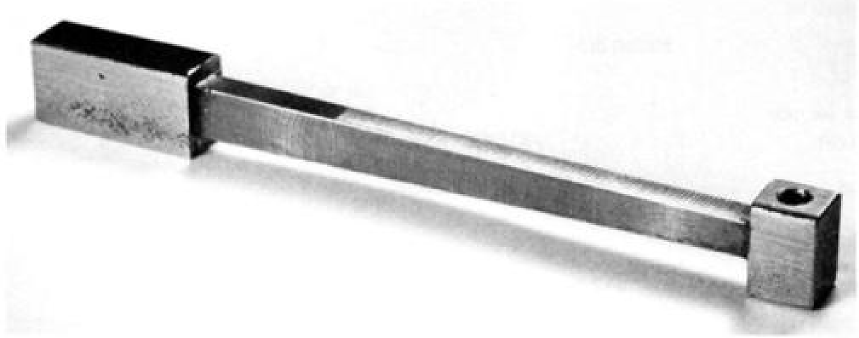
View from Rear of Engine



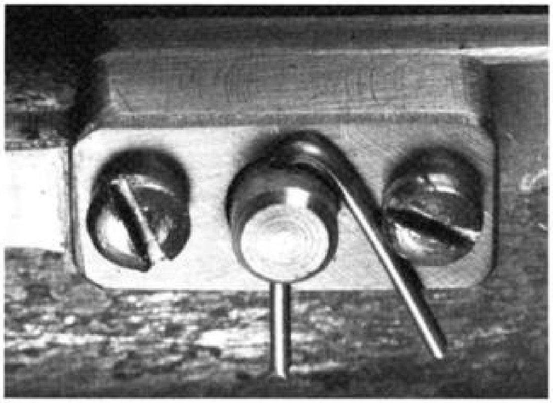
66



67



68



69

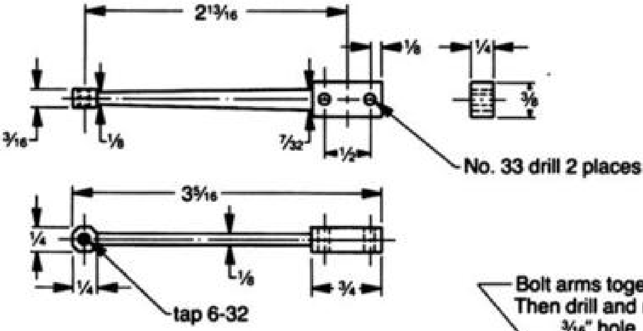
side of the engine cylinder block. Reposition the work in the four-jaw chuck, drill and machine the exhaust hole (Photo 64). Observe the steel plate used to protect the upper surface of the valve chamber. Again relocate the work in the chuck and machine down the valve stem guide sleeve. Remove the unit from the chuck, lay out and drill the location for the two bolt holes that will secure this section to the cylinder block.

Commence work on the intake valve unit by drilling and machining the valve seat (Photo 65). Ream out the hole that extends through the block to .125". Reposition the work with the opposite face outward. Machine out the valve stem guide sleeve. Bringing the outer width of the intake pipe portion of the unit down to size is, of course, another job best handled in the milling machine. Now lay out and drill the four bolt holes that will hold this unit atop the exhaust unit. Use these holes to spot the location for the four threaded holes in the top surface of the exhaust valve housing.

The exhaust valve unit must be properly lined up to the intake-exhaust port hole on the side of the cylinder block. A piece of 9/32" rod is inserted a short distance into the 9/32" port hole located on the back face of the exhaust valve section. The other end of the protruding 9/32" rod is inserted all the way into the port hole in the cylinder block. The two holes are now lined up. Position the exhaust valve unit square with the cylinder block and clamp it tight. Now spot drill the two holes to be threaded into the cylinder block.

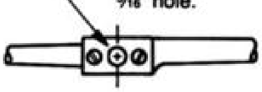
The Valves were machined from cold rolled steel (Photo 66). Turn the valve stems about 3/16" longer than called for – thus the tip of the stem can be cut off later on to eliminate the tailstock support hole. Machine the valve stem .0005" oversize and polish down to size with the aid of fine emery paper. Use fine grit valve grinding compound to seat them properly against the valve seats.

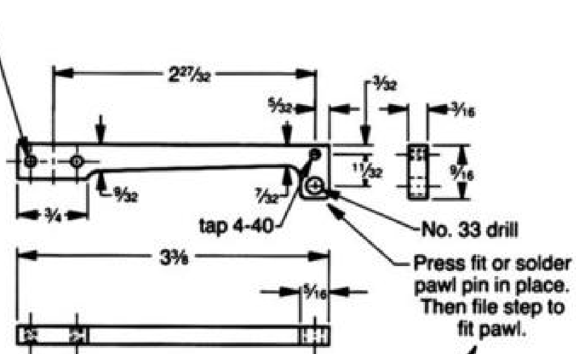
The long Rocker Arm (Photo 67) is milled from two pieces of rectangular steel and bolted together at midsection. Drill and ream the 1/4" pivot shaft hole *after* the two sections are bolted together. Photo 68 illustrates how one of the rocker arm sections was milled down to lighten it. When assembling the completed rocker arm on the engine, slip a piece of .036"


2 13/16
1/8
1/4
3/8
3/16
1/8
7/32
1/2
No. 33 drill 2 places
3 5/16
1/4
1/8
1/4
3/4
tap 6-32

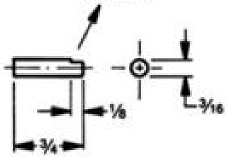
ROCKER ARM
steel
Left-hand Section
1 required

Bolt arms together. Then drill and ream 3/16" hole.

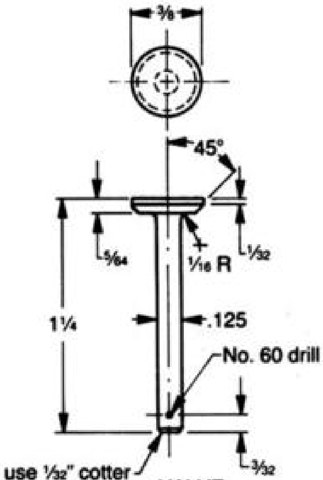



Locate 2 bolt holes using left hand section. Tap 4-40
2 27/32
3/32
5/32
3/16
11/32
9/16
9/32
7/32
3/4
tap 4-40
No. 33 drill
Press fit or solder pawl pin in place. Then file step to fit pawl.
3 3/8
5/16

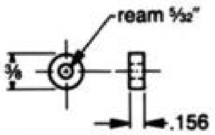
ROCKER ARM
steel
Right-hand Section
1 required



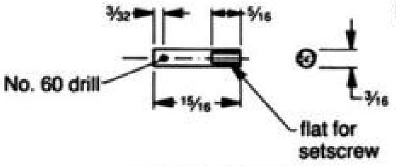
PAWL PIN
steel
1 required


3/8
45°
5/64
1/16 R
1/32
1 1/4
.125
No. 60 drill
3/32
use 1/32" cotter pin in hole

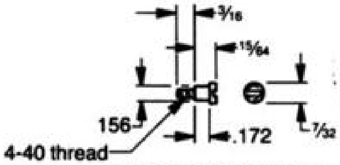
VALVE
steel
2 required


ream 5/32"
3/8
.156

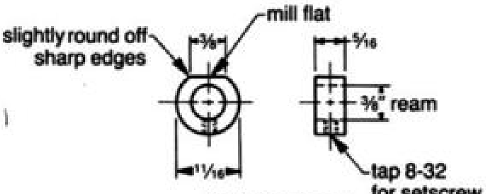
CAM ROLLER
steel
1 required


3/32
5/16
No. 60 drill
15/16
3/16
flat for setscrew

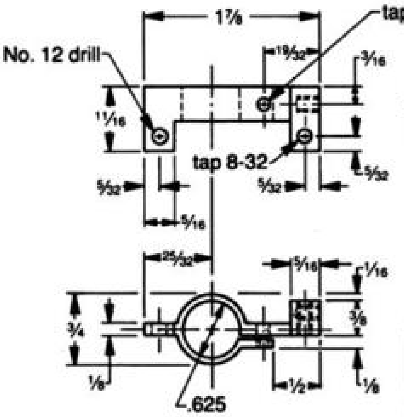
ROCKER ARM SHAFT
steel
1 required

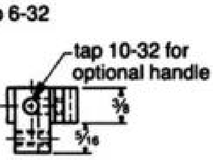

3/16
15/64
156
4-40 thread
.172
7/32

CAM ROLLER SHAFT
steel
1 required

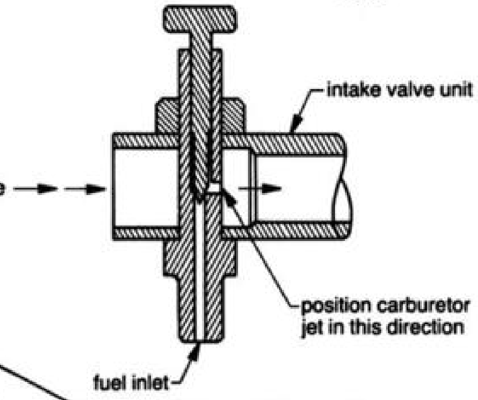

mill flat
slightly round off sharp edges
3/8
5/16
3/8" ream
11/16
tap 8-32 for setscrew

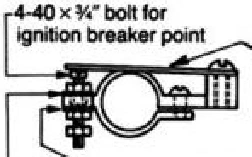
IGNITION CAM
one required
CRS

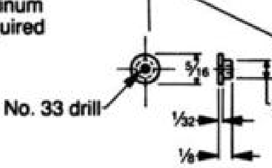

1 7/8
No. 12 drill
19/32
3/16
11/16
tap 8-32
5/32
5/32
5/32
5/16
25/32
5/16
1/16
3/4
3/8
1/8
1/2
1/8
.625


tap 6-32
tap 10-32 for optional handle
3/8
5/16

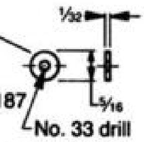
IGNITION BRACKET
aluminum
1 required


intake valve unit
air intake
position carburetor jet in this direction
fuel inlet

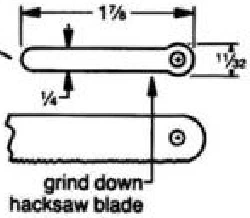

4-40 × 3/4" bolt for ignition breaker point


5/16
.187
No. 33 drill
1/32
1/8

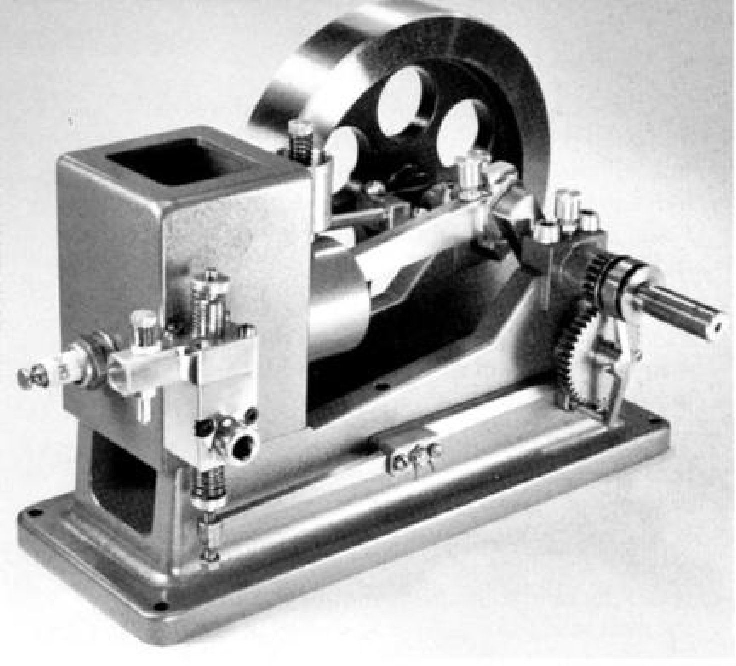
INSULATED BUSHING
nylon or plastic
1 required


1/32
5/16
No. 33 drill

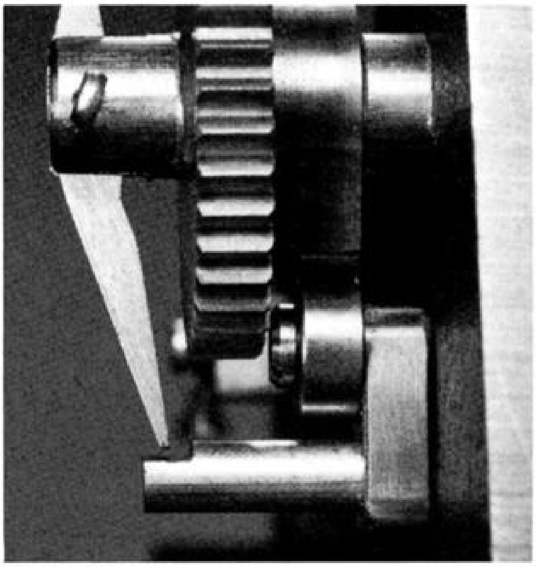
INSULATED WASHER
nylon or plastic
1 required


1 7/8
11/32
1/4
grind down hacksaw blade

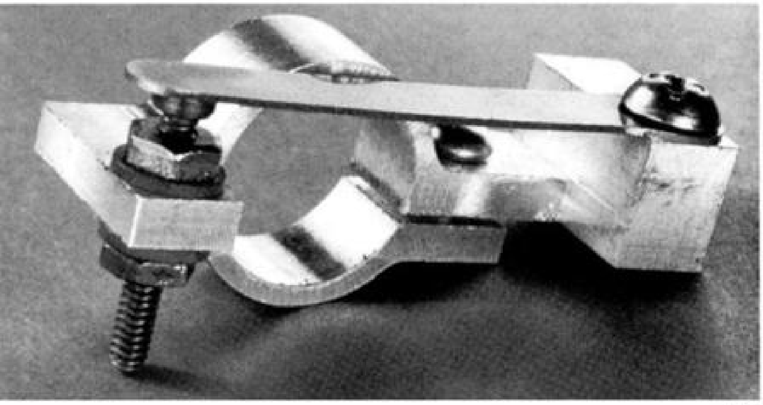
FLAT SPRING CONTACT POINT
1 required



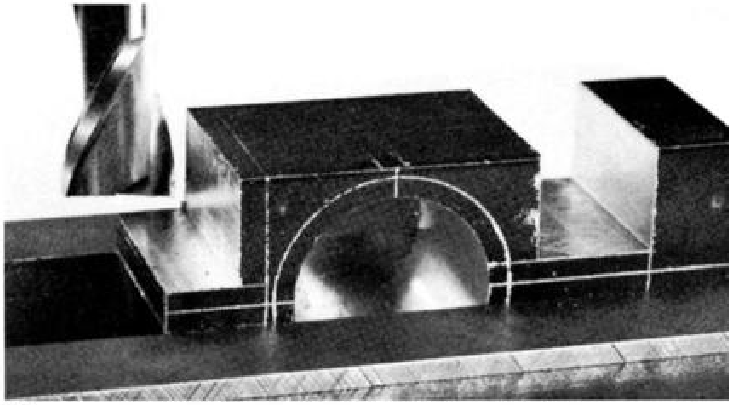
70



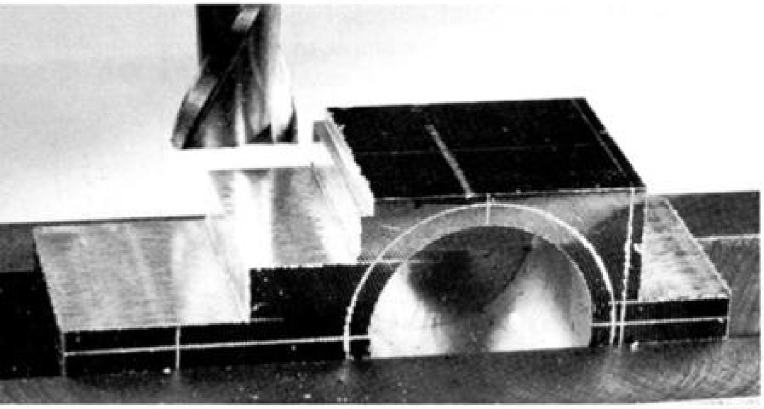
71



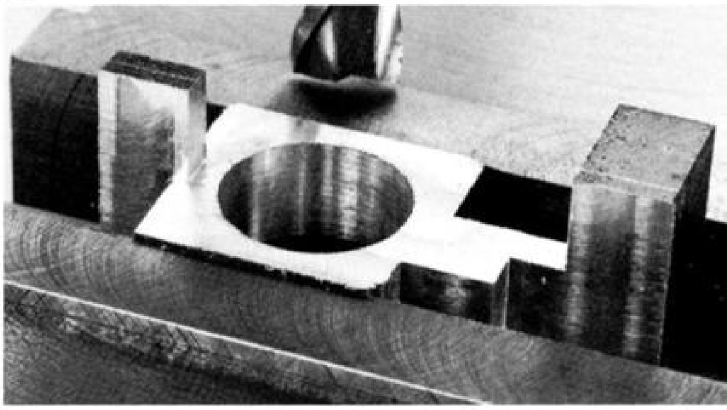
72



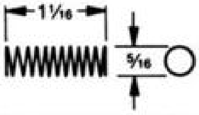
73



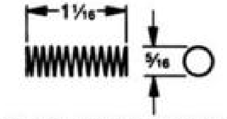
74



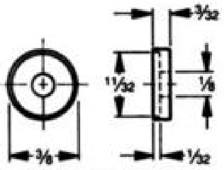
75



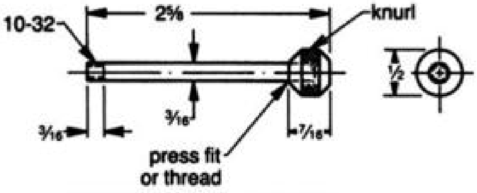
EXHAUST VALVE SPRING
11 coils .024" music wire
1 required



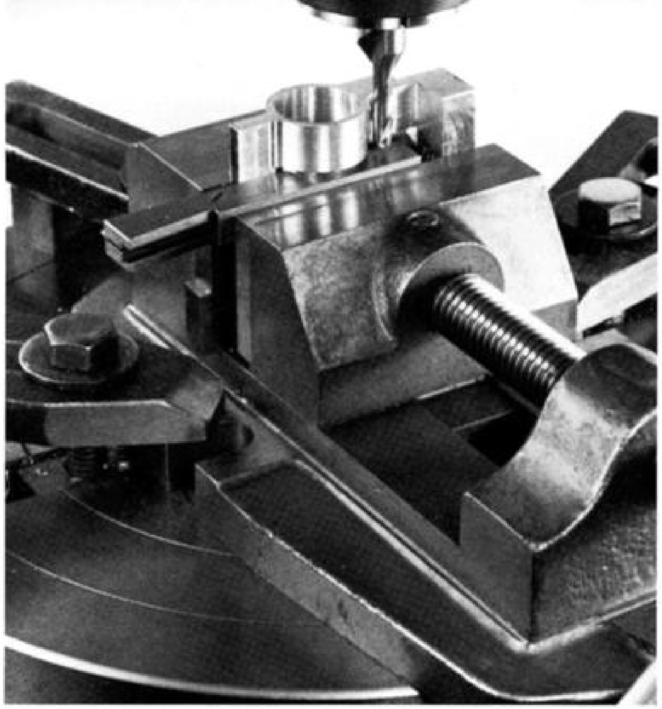
INTAKE VALVE SPRING
12 coils .013" music wire
1 required


3⁄32
1¹⁄₃₂
1⁄8
3⁄8
1⁄32

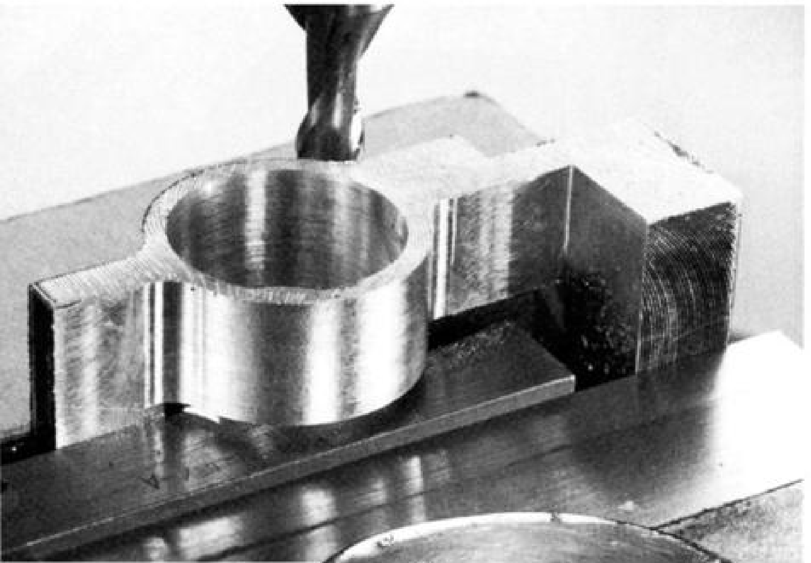
VALVE KEEPER
aluminum, brass or steel
2 required


10-32
2⅝
knurl
½
3⁄16
3⁄16
7⁄16
press fit
or thread

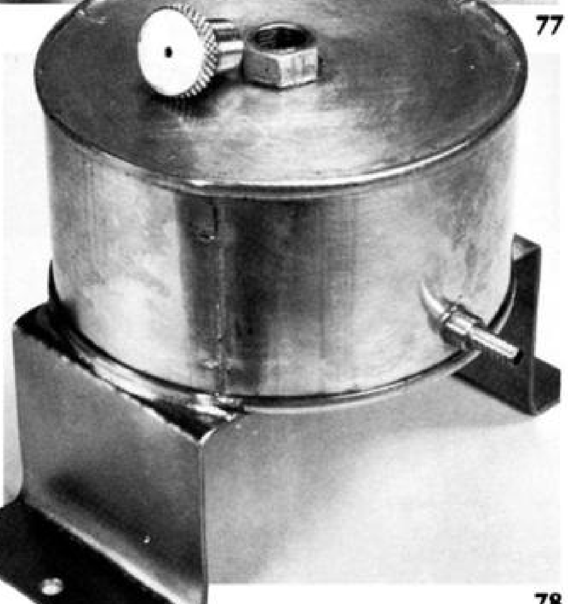
IGNITION BRACKET HANDLE
(optional)
aluminum or steel



76



77



78

or .040" music or spring wire into the pin hole and bend it around to bear against the bolt head (Photo 69). Pressure from this spring helps to keep the Cam Roller up against the Cam. Another view of the rocker arm is visible in Photo 70.

Note in Photo 71 that the tip of the Governor Pawl should just clear the step on the catch arm when the cam roller is on the highest point of the cam.

The Ignition Point Bracket (Photo 72) was machined from an aluminum block – almost any type of metal could have been employed. Scribe the layout lines on the stock piece and chuck it up in the lathe. Drill and bore (or ream) the hole to 5/8". Now mount the work in the mill vise and machine as shown in Photo 73. Observe that the cuts are kept about 3/32" away from the circular line around the hole. Reposition the work with the side just milled face down in the vise. Machine as in Photo 74.

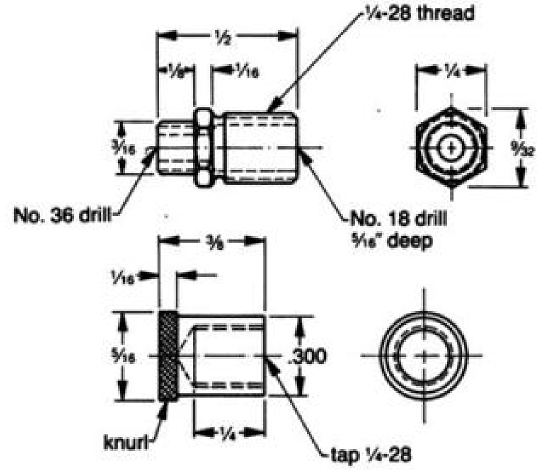
Again stay away from the circular line. Now position the work and mill it out similar to Photo 75. Next, clamp the work in a small vise and center it on a rotary table so that the 5/8" hole in the work is running true (Photos 76 and 77). A 3/16" end mill was used to form the curve around the hole.

The gas tank is easily built with the aid of a discarded tuna can (Photo 78). The gasoline level in the tank should be about 1/2" below the center line of the carburetor air intake pipe. Therefore, build a bracket about 1 1/2" tall out of sheet metal and solder it to the base of the tank. Use a length of 1/8" gasoline proof plastic tubing or neoprene rubber tubing to connect the tank to the carburetor.

The remaining parts of the engine to be built are of simple construction, hence no explanation will be given.

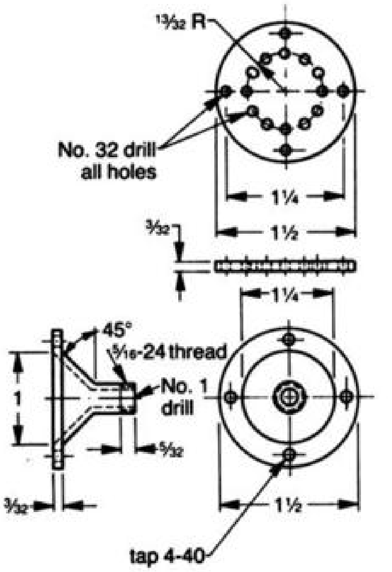
Prior to painting the engine base unit, its appearance is improved by forming a fillet or cove around the angle iron uprights. Use *Bondo* auto body plastic filler (the two-part type). Smooth it on with a 1/2" ball bearing soldered to a metal tube or rod (Photo 79). A child's glass marble could also be attached to a rod handle with an instant type super glue.

To time the exhaust valve, remove the flywheel from the timing gear side of the engine; remove the governor pawl and spool, also. Remove the four crankshaft bearing bolts and lift up the crankshaft horizontally just enough to disengage the gears. At this time the piston should be about 1/8" from the end of its

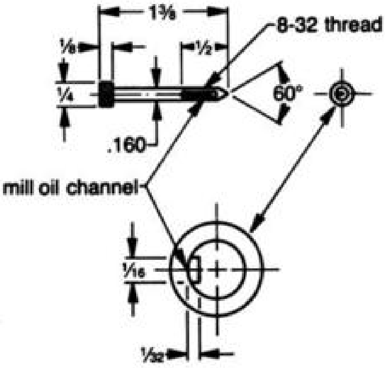

1/4-28 thread
1/2
1/8
1/16
1/4
3/16
9/32
No. 36 drill
No. 18 drill
5/16" deep
3/8
1/16
5/16
.300
knurl
1/4
tap 1/4-28

GREASE CUP
brass, aluminum or steel
3 each required

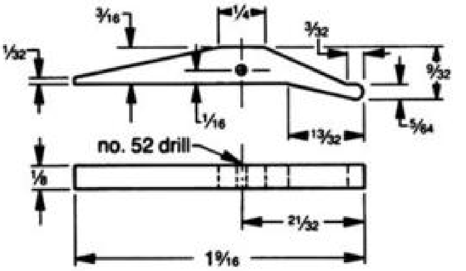
79


13/32 R
No. 32 drill
all holes
1 1/4
3/32
1 1/2
1 1/4
45°
5/16-24 thread
No. 1
drill
1
5/32
3/32
1 1/2
tap 4-40

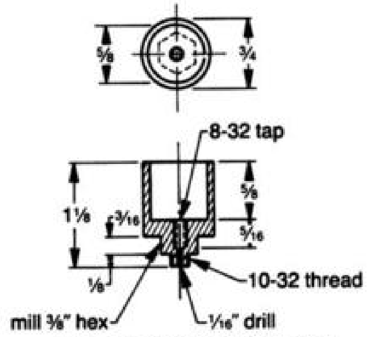
MUFFLER
(optional)
aluminum, brass or steel


1 3/8
8-32 thread
1/8
1/2
1/4
60°
.160
mill oil channel
1/16
1/32

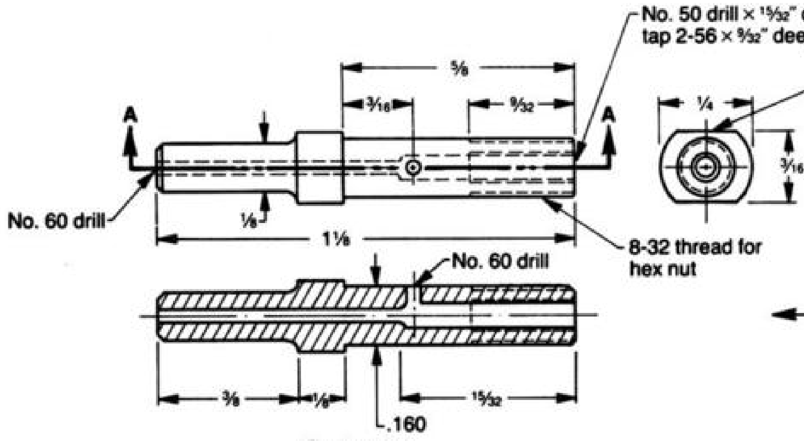
OIL CUP VALVE
aluminum, brass or steel
1 required


3/16
1/4
3/32
1/32
9/32
1/16
13/32
5/64
no. 52 drill
1/8
21/32
1 9/16

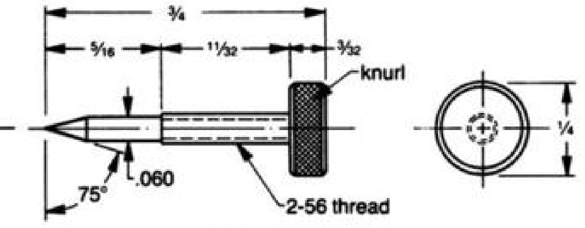
GOVERNOR PAWL
steel
1 required


5/8
3/4
8-32 tap
1 1/8
3/16
5/8
5/16
1/8
10-32 thread
mill 3/8" hex
1/16" drill

ENGINE CYLINDER OIL CUP
aluminum, brass or steel
1 required


No. 50 drill × 15/32" deep;
tap 2-56 × 9/32" deep
5/8
3/16
9/32
A
A
1/8
No. 60 drill
1 1/8
8-32 thread for
hex nut
mill 2 flats
1/4
3/16
No. 60 drill
3/8
1/8
15/32
.160
Section A-A

CARBURETOR JET
aluminum, brass or steel
1 required

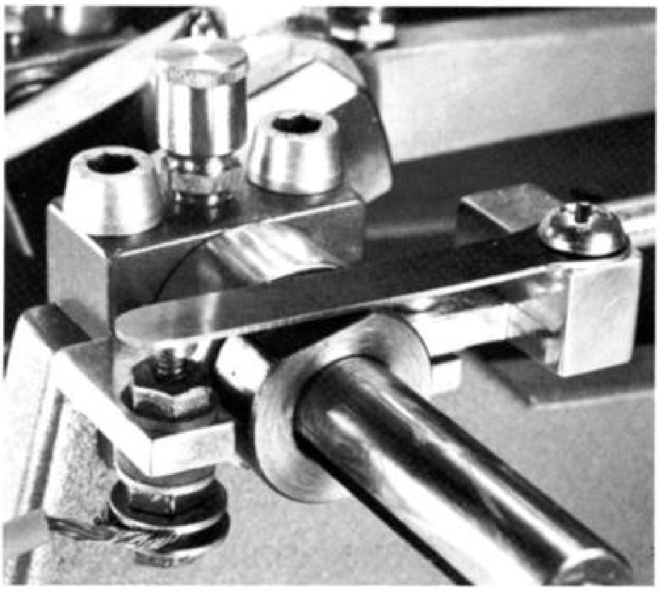

3/4
5/16
11/32
3/32
knurl
1/4
75°
.060
2-56 thread

NEEDLE VALVE
brass, steel or aluminum
1 required

outward travel. Now rotate the cam gear in a counterclockwise direction until the rocker arm just begins to open the exhaust valve. Hold the cam gear in this position and lower the crankshaft back into place. Check that the piston is still located about ⅛" in from the end of its stroke. Now rotate the crankshaft slowly and observe the exhaust valve action. Since this is a four-cycle engine, the exhaust valve will be lifted only every other revolution of the crankshaft. The valve should begin to open just before the piston reaches the end of its power stroke and close about the time the piston reaches the end of its inward stroke.

Ignition timing is simple. The flat section on the ignition cam should just start to lift the flat spring from the insulated ignition point when the piston has just passed top dead center as in Photo 80. If the ignition bracket unit is not clamped too tightly on the crankshaft bearing journal, it's possible to advance or retard the ignition timing by merely rotating the ignition unit slightly one way or the other by means of its extension handle. This allows you to adjust the spark timing when the engine is running.

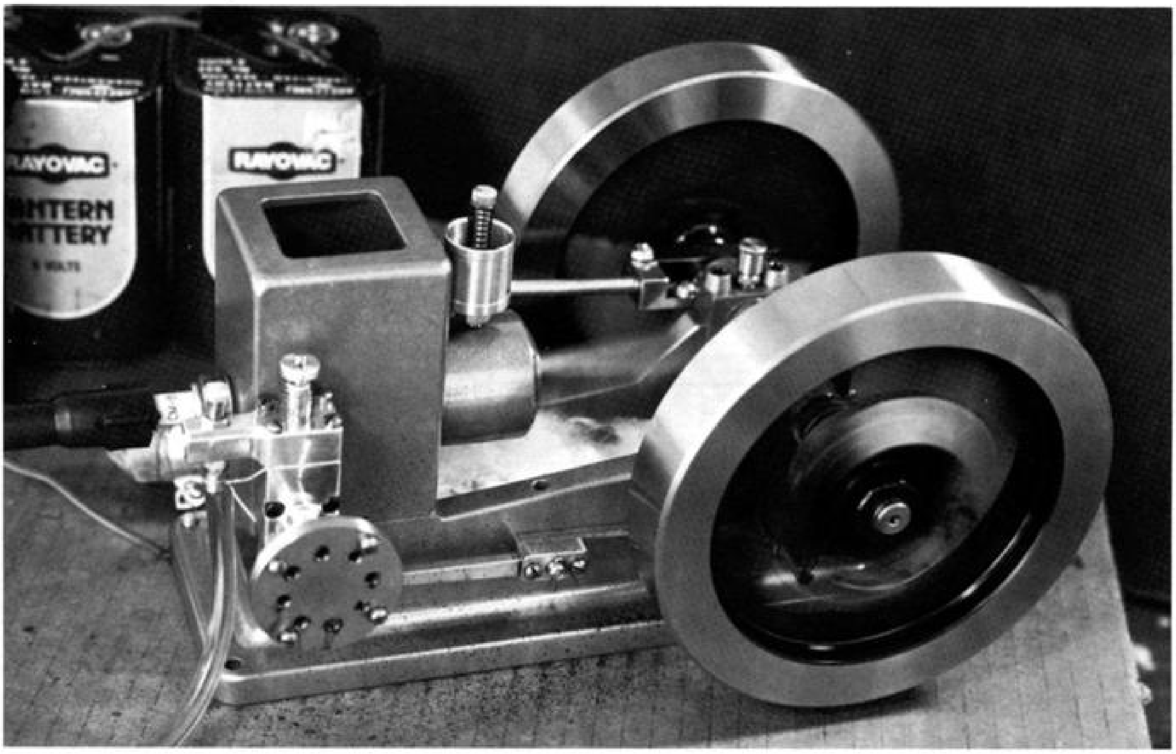
Just prior to the final bolting together of the intake and exhaust units, smear a thin layer of Permatex Silicone RTV Blue *Form-A-Gasket* material onto one of the mating surfaces. Also apply a thin layer between the exhaust unit and the cylinder block when bolting in place.



80

This type of gasket material allows you to remove the valve units at any time, if necessary, without using a crowbar to do it. Don't allow any dirt to enter the valve chambers; one little piece wedged under either valve seat and the compression disappears!

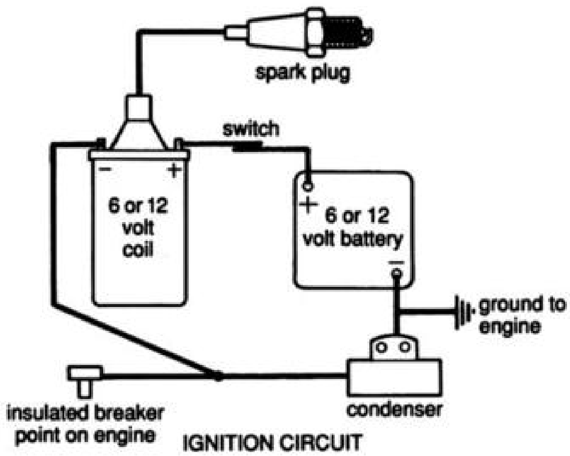
When the engine is running, its speed is regulated by the amount of spring tension on the governor weights; too much tension and the engine will only run fast and never "hit or miss." If the spring tension is too weak the



engine will "hit and miss" before reaching the proper speed and will die.

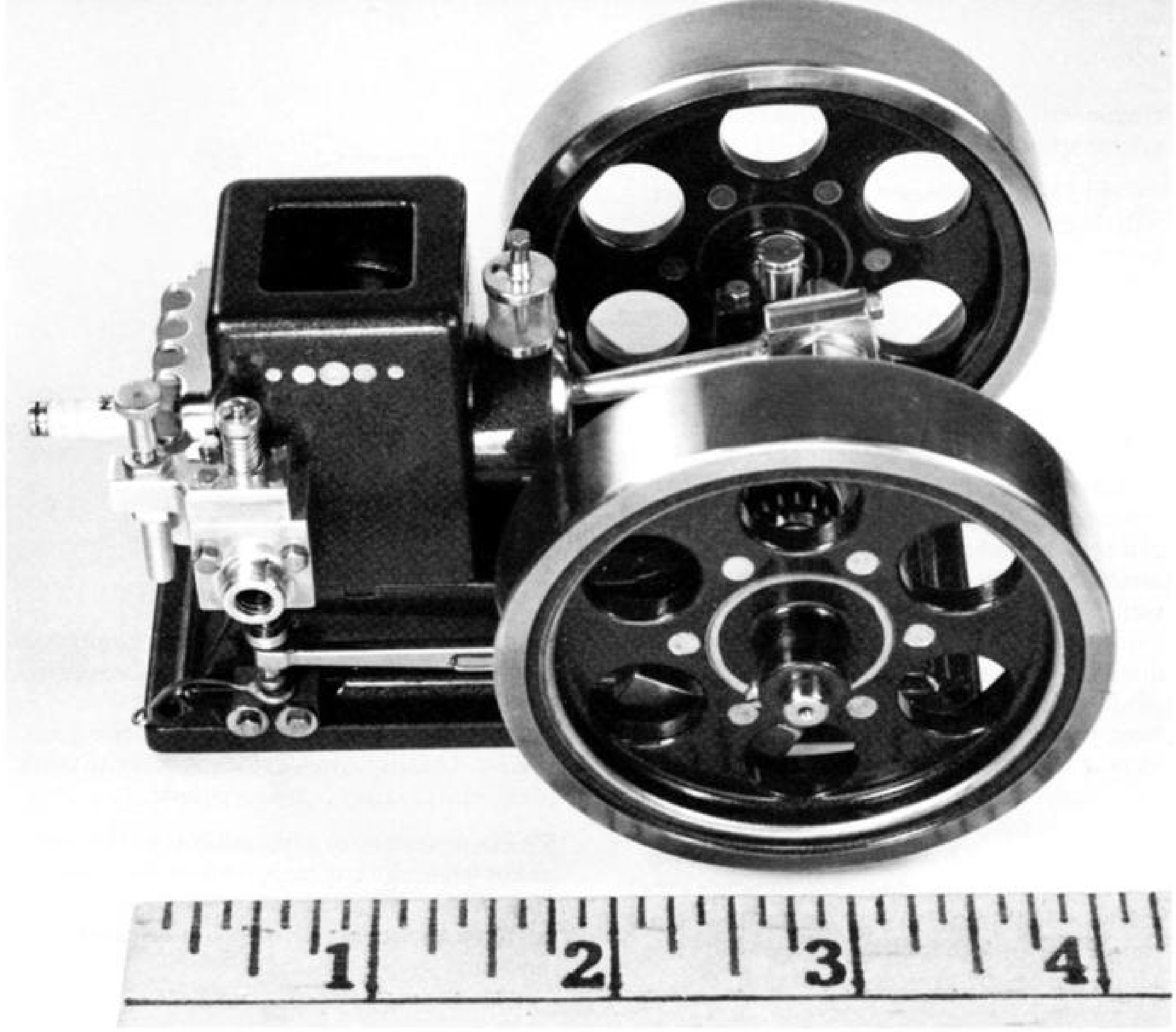
An old 12- or 6-volt auto coil and condenser will do for the ignition. One 6-volt lantern battery is sufficient for the 6-volt coil. Use two 6-volt lantern batteries hooked in series to produce 12 volts if the 12-volt coil is employed. As an option for the auto coils and condensers, those for a motorcycle could be used – the main advantage here being their smaller size.

I prefer adding a small amount of two-cycle motor oil to regular gasoline when breaking in a new engine; others prefer to use Coleman camp stove fuel instead of gasoline. When attempting to start the engine for the first time, open the carburetor needle about a half-turn from the closed position. Place your finger *momentarily* over the air intake pipe while you give the flywheel a vigorous turn. Keep your eye on the intake valve stem; as soon as you see it jump downward, remove your finger from the intake. Continue with vigorous turns of the flywheel until the motor starts. If it runs a few revolutions on its own power and then dies, this could indicate a fuel mixture that's too rich – or, on the other hand, simply not enough fuel. So, by trial and error, adjust the needle valve in or out until the engine continues to run. *Ignition, compression,* and *carburetion* are the three main factors to consider when an engine won't start – assuming that the valve and spark timing are correct. Usually a weak spark across the spark plug points is the offending culprit.



IGNITION CIRCUIT

It's not necessary to add a coolant to the water jacket when the engine is not running under a load. When "hit and missing," it hardly warms up. Keep all moving parts well lubricated – and have fun!



1

Smallest "Hit & Miss" Gas Engine?

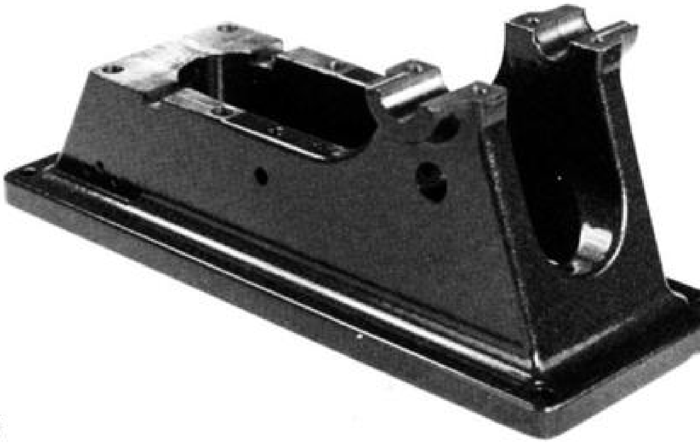
After completing a very enjoyable project of building a baby "hit & miss" engine, I began to wonder if someone has constructed a smaller one. I have no idea – but I do know that there are many "hit & miss" model engines that are *much* larger!

This tiny engine is slightly over 4" long – the flywheels are 2-1/2" in diameter (Photo 1). The "large" engine in Photo 2 is considered a "small" engine; it has a 1" cylinder diameter. My little engine has a 1/2" bore.

All of the engine parts were machined from solid pieces or blocks of metal, including the steel base section (Photo 3). The piston is aluminum with cast iron rings, and the con rod is brass (Photo 4). The penny in Photo 5 illustrates the size of the valves, each of which has a stem diameter of 1/16" and a 3/16" head diameter. Note in Photo 6 the simplified governor mechanism. The governor weight pivots sideways, instead of the usual up and down motion. The ignition points are also very elemental (Photo 7). The upper ignition point was soldered to the bottom end of the rocker arm adjusting screw. The lower point is bolted to a fiber insulating block. Note the short copper lead wire extending away from the bottom point.

It was more expedient to solder the roughed out bronze bearing sleeves directly to the crankshaft (Photo 8); then the crankshaft was mounted between centers in the lathe and the sleeves cut to proper size. Another advantage of this method is a slightly larger amount of bearing surface against the steel mating surfaces in the engine base.

2



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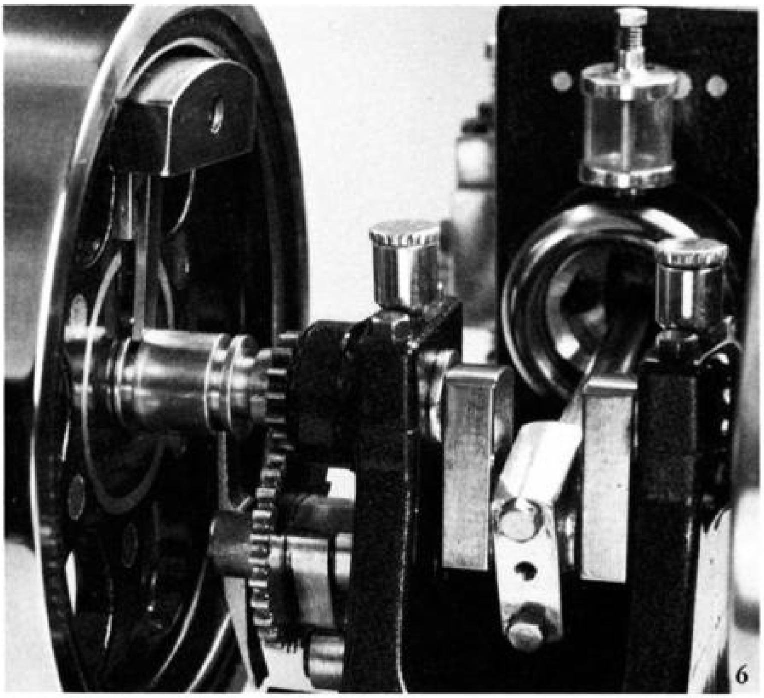
4

IN GOD WE TRUST
LIBERTY
1986

5



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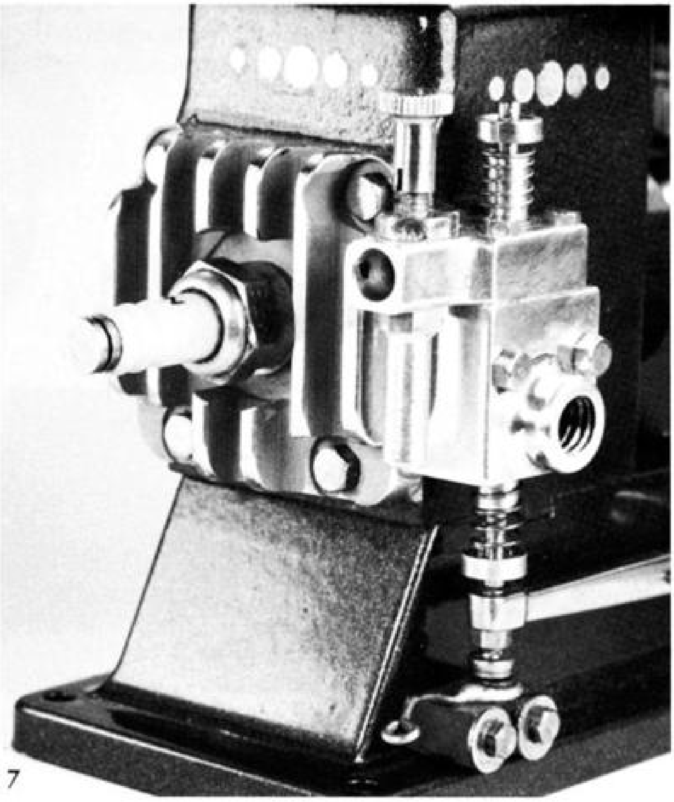

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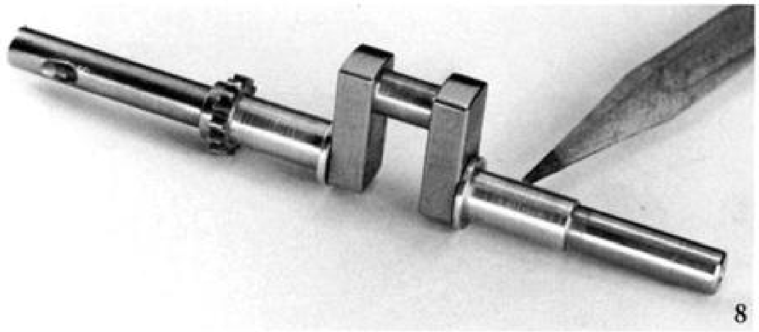

8

Machining the crank throw journal is usually a haphazard experience – especially on a small crankshaft. Here's a more foolproof method of doing the job – provided you have a vertical mill or vertical mill attachment for your lathe.

Rough out a groove for the crank throw (Photo 9). Now mount the work between centers on the mill table. If you have a dividing head and tailstock, use them to support the work. If not, use a setup similar to the one in Photo 10.

Machine two true running 60° centers from round 1/2" crs. Clamp them in the V-grooves on a pair of V-blocks. Position the two V-blocks *parallel* to the mill table. Lubricate both center points before mounting the work. The V-block clamp is employed to remove all play between the workpiece and the centers. Before proceeding further, examine your end mill – it should be *sharp!* By carefully honing a very small radius on each cutting edge of the mill, it will improve the finish on the work. Now position the end mill *exactly* in the center of the previously cut groove (Photo 10). Then lock the table for longitudinal travel. Use the cross slide to advance the workpiece toward you enough to clear the cutter.

Remember, the outer end cutting edges of an ordinary end mill are hollow ground at a 2° angle. As an example, let's assume that we have centered the end mill directly over the center line of the workpiece and gradually lowered the revolving cutter while slowly turning the work by hand. True, the crank journal would be machined to a cylindrical form – but it would be barrel shaped. Therefore, it's necessary to feed the cutter gradually, by steps, into the work from the side. Thus, only the very outer tips of the end mill will be doing the cutting and the result will be a straight cylindrical journal. *Always* keep a firm grip on the workpiece while the cutter is in motion.

To begin work, lower the end mill slightly – just enough to touch the highest of the square edges on the journal blank. Now move the end mill away to clear the work and lower it .010". Lock the vertical movement of the spindle and set the spindle RPM to a fairly fast speed. Firmly grasp the workpiece with your fingers (Photo 11) and slowly revolve it clockwise as the cutter is advanced into the work. You'll feel the jolting vibration as the cutter makes contact. Revolve the blank several revolutions. Then advance the cross slide about .010" and again revolve the blank.

Continue advancing the cross slide by .010" steps until the end mill center line has just passed *beyond* the center line of the workpiece. Now back off the end mill; lower it about .010" and repeat the cutting process until the journal is round. Now lower the end mill in increments of only .005", and as you approach the correct diameter for the shaft, lower the end mill only about .001" at a time and advance

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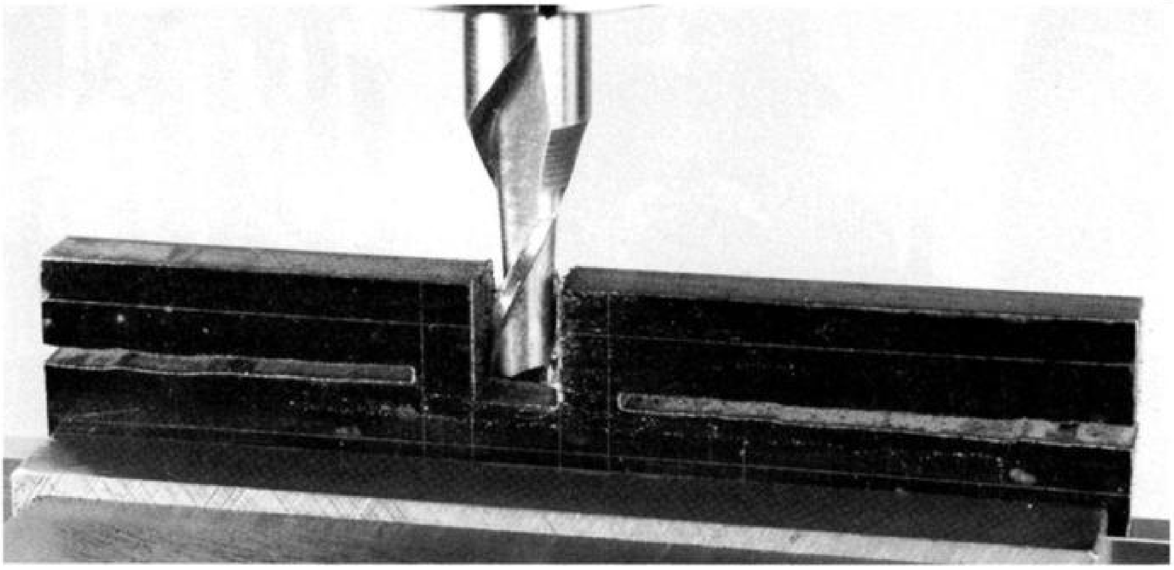

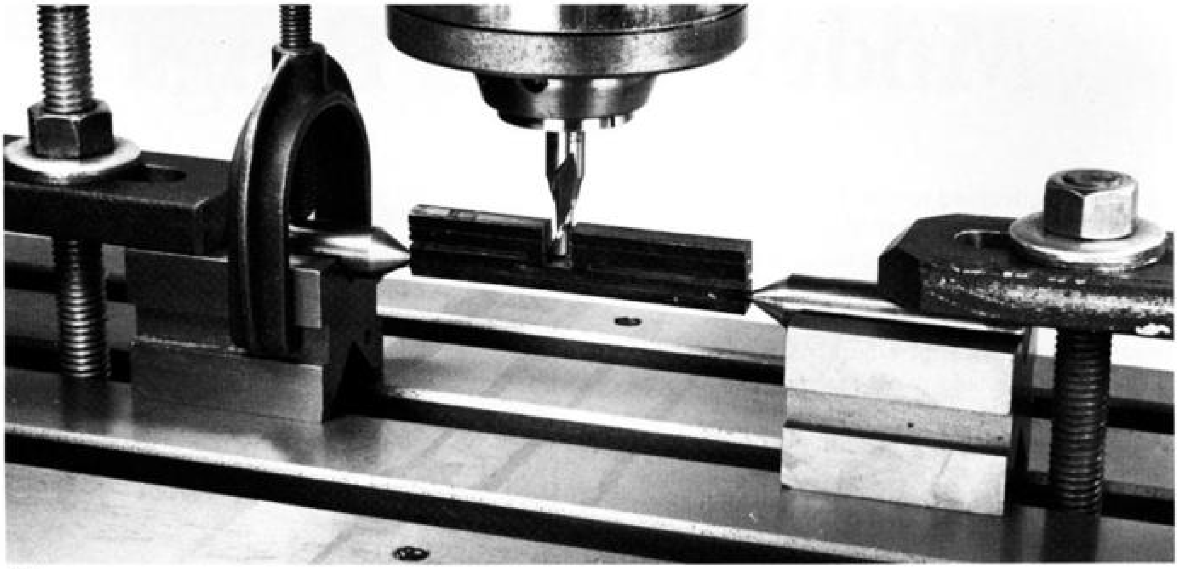

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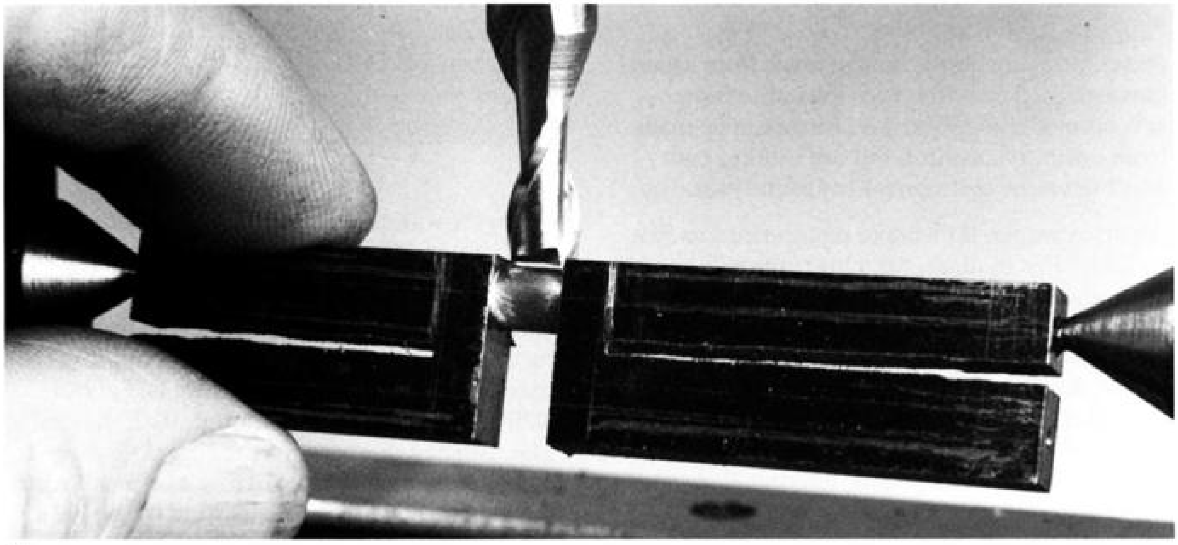
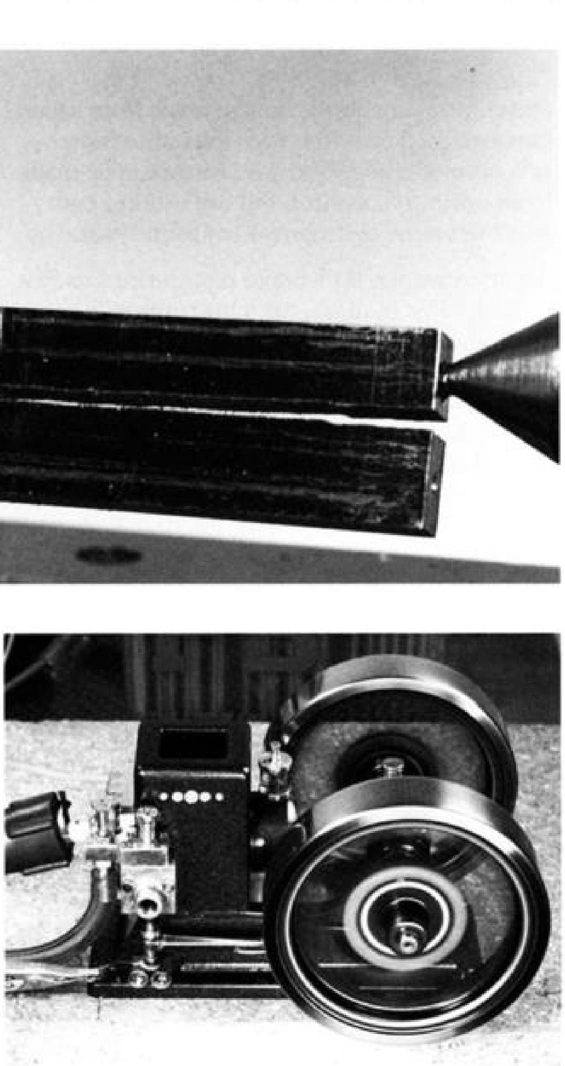


11

it into the work about .005" for every three or four revolutions of the blank – in other words, sneak up on that elusive critical journal diameter you desire. I prefer leaving the diameter about *.00025"* oversize; then by transferring the work back to the lathe, it's easy to polish it to size with a long narrow strip of very fine emery paper. The rest of the crankshaft is now completed in the usual manner in the lathe.

For me it's always a thrill to see one of these "hit & miss" engines chugging away on the test block (Photo 12). This baby engine is surprisingly quiet – even when minus a muffler – just makes a cute little pop! pop!



12

Model Piston Rings

Once I decided to build my first model "hit and miss" gasoline engine, I purchased the plans and basic castings from Coles Power Models, Inc., in Ventura, California. Since I wanted to build from scratch as many of the engine parts as I could, I didn't order ready-made piston rings, timing gears, etc. Well, I left the making of the piston rings as the last item to be finished. Why? Because I hadn't the foggiest notion as to how a piston ring is manufactured! I have *never* seen an article on that subject. So, after many trials and errors I was able to come up with a method that works just fine. Some examples are seen in Photo 1.

Piston rings are best if they're made from special close grained cast iron rods available from several model supply stores. Rings can be made from ordinary cast iron but are weaker and don't have the springiness of special cast iron.

An an example, let's make piston rings to fit a cylinder 1¼" in diameter. Our rings will be 3/32" wide and about 3/64" thick. There's a ratio between the diameter of a ring and the thickness of a ring. If a commercial piston ring of 1⅝" diameter is 1/16" thick, then a ring of 1¼" diameter should be about .050" thick. If a ring is 1" in diameter, then the thickness would be about .040". In other words, if a ring 1" in diameter was made as thick as a larger ring (1/16"), it would be too stiff and might break during the attempt to install it on the piston.

1

2

Chuck up a piece of cast iron in the lathe and turn the OD and ID for a length of not less than 3/8" (Photo 2). Rough out the OD about .020" oversize and the ID about .020" undersize. The finished diameter of the ring is governed by the *thickness* of the slitting saw used to cut the gap in the ring. I used a circular saw .020" thick; it's advisable to stick fairly close to that dimension. The circumference of a circle is equal to the diameter × 3.1416. Therefore, a cylinder diameter of 1.250" × 3.1416 equals 3.927". Since we are going to cut a gap of .020" from the circumference of the ring we must add on .020" to the original 3.927". So, 3.927" + .020" = 3.947". Now, 3.947" ÷ 3.1416 = 1.256" – that's the finished diameter of our ring. To maintain a wall thickness of .050" for the ring, we simply subtract .100" (twice the thickness of the ring) from 1.256", and that equals 1.156" as the finished inside diameter. It's best to machine the OD to size – don't try to file or sand it to size.

To cut off the rings from the tube, it's advisable to grind a special stubby cutoff tool (Photos 3 and 4). Have clearance on each side and a front angle of 10° or 15°. This allows the tool to cut through first on the right-hand side and will part the ring cleanly from the tube.

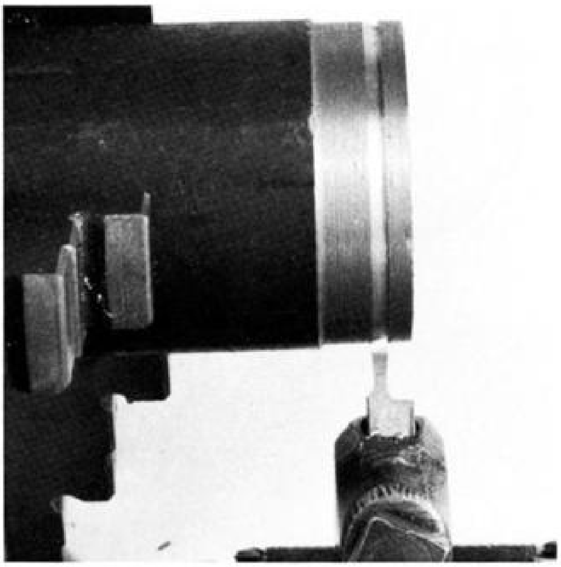
Cutoff tools are notorious for chattering; it helps to keep the front clearance angle of the tool to a minimum. To set the cutoff tool properly in position for cutting the width of the ring, swing the compound slide parallel to the axis of the lathe. Set its micrometer collar at zero. Now move the carriage to the left until the *left* side of the tool is in position to shave off .002" or .003" from the face or outer end of the tube. Lock the carriage so it can't move. Face off the end. Now we'll have to measure the width of the ring groove in the piston. We'll assume it's .094". It's best to make the ring .001" or .002" wider than the groove. (Better too wide than too narrow.)

With a micrometer, measure the width of your cutoff tool. Assuming that it's .060" wide, we add .060" plus .094" for a total of .154" – but for insurance purposes, it's best to tack on at least another .001" for a final figure of .155". This is the amount to advance the cutoff tool to the left by turning the compound slide crank. Watch the micrometer collar on it until .155" has been reached. Use your slowest spindle speed and slowly advance the cutoff into the work. Take your time as the tool doesn't have very far to go before it parts the ring from the stock piece. After parting, back off the tool from the work. Reset the compound slide micrometer collar to zero. Unlock the carriage and move it to the left a fraction; lock the carriage and face off the end of the tube as before and repeat the process for the second ring.

Using fine emery paper placed on a flat surface, lightly sand each side of the rings. Now try to insert a portion of each ring into the piston grooves; probably they'll still be slightly too wide. Again carefully sand each side by pressing the ring down on the emery paper with your fingers and use a circular motion as if washing a window. This operation could be done on a surface grinder and magnetic chuck...if you're blessed to have them!

The finished rings should be about .001" narrower than the grooves in the piston; they should slip freely into the grooves without binding – but not sloppily. Next, clamp the ring in the side of a vise with a small portion of the ring exposed (Photo 5) and cut the gap.

Heat-treating the rings is a very simple operation. You will need a piece of 3⁄16" square steel about 2" or 3" in length; place this rod and a piston ring on a flat surface. With both hands, gently open the piston ring gap just enough to insert the tip of the rod. Now clamp the rod (with the ring mounted on it) together



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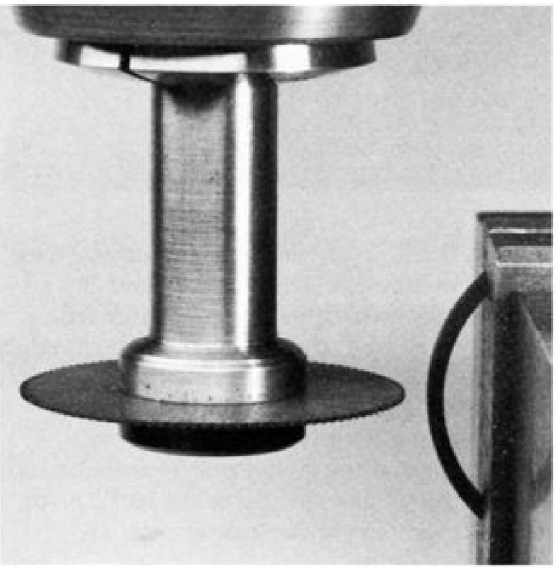

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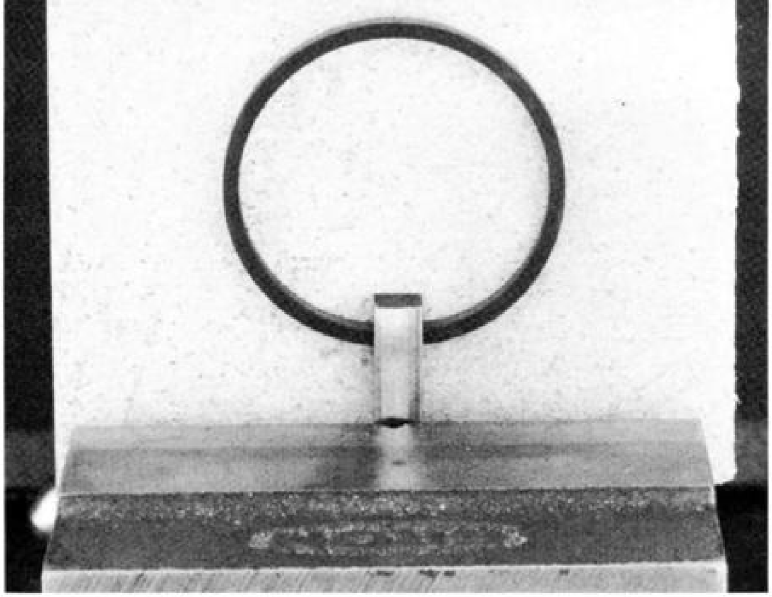

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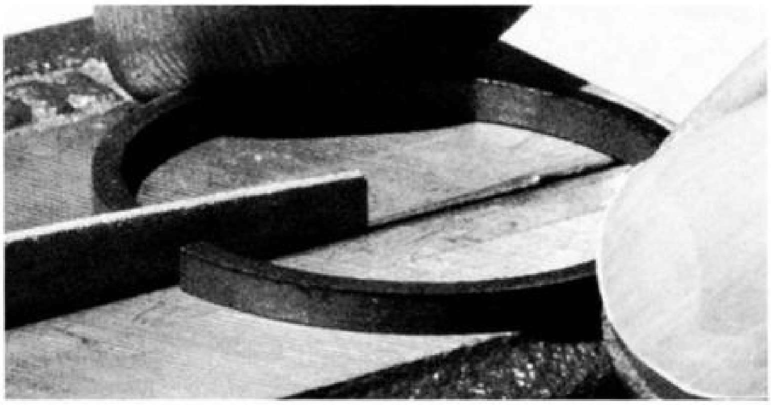

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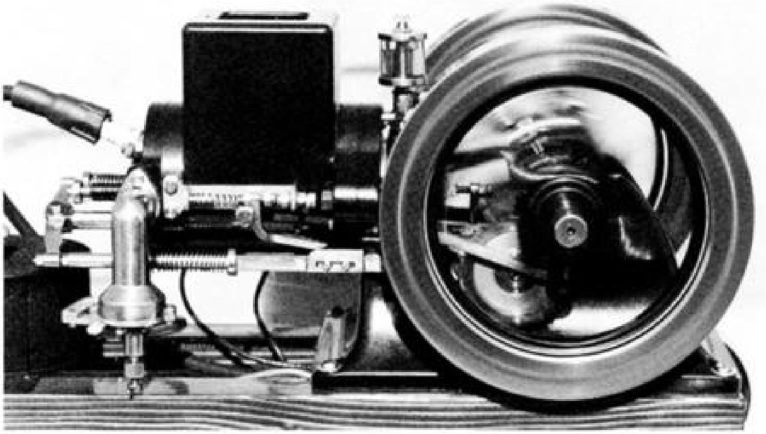

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with a "baffle" plate in a vise (Photo 6). I used a piece of asbestos board for the plate, but a piece of flat steel from 1/16" to 1/4" thick will work just as well. An ordinary propane torch is used for heat, the idea being to bring the ring to a medium cherry red color as uniformly as possible. In order to accomplish this, it's important that the piston ring be placed about 1/32" in *front* of and *parallel* to the baffle plate; this allows some of the heat to circulate behind the ring.

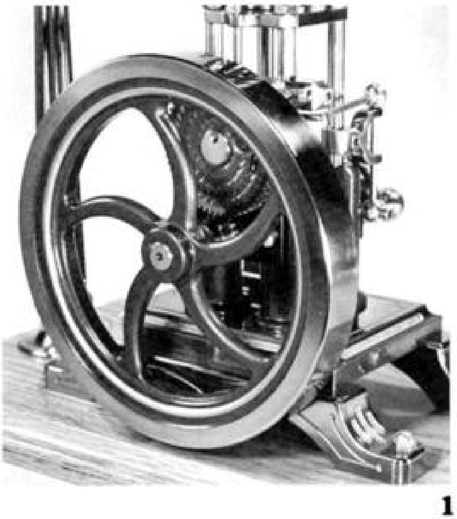
It's best to do the heat treating in a semi-dark area; this allows you to easily see when the first dull glow appears on the ring. After lighting the torch, slowly bring the tip of the long blue flame to bear squarely at the center of the circle formed by the piston ring. Don't point the flame directly at the ring. In 10 or 15 seconds the ring will take on the first dull glow. If a portion of the ring appears hotter than the rest, move the flame slightly away from that area. Continue applying heat until the ring has reached a nice cherry red color; then turn off the torch. The tips of the ring that are touching the steel spreader will not get as hot as the rest of the ring, but that's okay. Let the ring cool by itself. You'll find now that the ring has lost most of its grip on the spreader and has assumed a nice wide gap.

The final operation is to fit the rings to the cylinder. First, check to see if the rings can be pushed into the cylinder; hopefully they will not. You'll need a *thin* flat needle file, or if you have an auto ignition breaker point file, it could be used. At worst a steel fingernail file will work, although it won't cut very fast. Clamp the file in a vise (Photo 7) and squeeze the ring snugly against both sides of the file. Slide the ring back and forth while keeping the file aimed as closely as possible at the center of the ring. Continue checking to see if the ring will go into the cylinder; when it does, take the piston and push the ring about ½" into the cylinder. Measure the gap in the ring with a feeler gage. I made my gap .004", so when you reach that distance it's time to quit. With the ring seated *squarely* in the cylinder, hold the cylinder pointed at a bright light. Using a magnifying lens, carefully examine the perimeter of the ring where it mates with the curve of cylinder wall. Any portion of the ring where light shines through means the ring is warped, probably caused by an uneven heat treatment. However, this problem is rare, and so far it hasn't happened to me.

Before slipping the rings onto the piston, it's best to file a small bevel on the lower sharp edge of each end of the ring at the gap. This will slightly reduce the strain on the ring when mounting it and help prevent scratches on the piston – especially an aluminum piston.

After your engine is completely assembled and you're ready to start it for the first time, you'll find that the compression is quite weak. Don't worry. When you finally get it running and the rings have a chance to wear in, you'll be amazed at the compression. It's most facinating to watch these little engines chugging merrily away.

Curved Spoke Flywheel



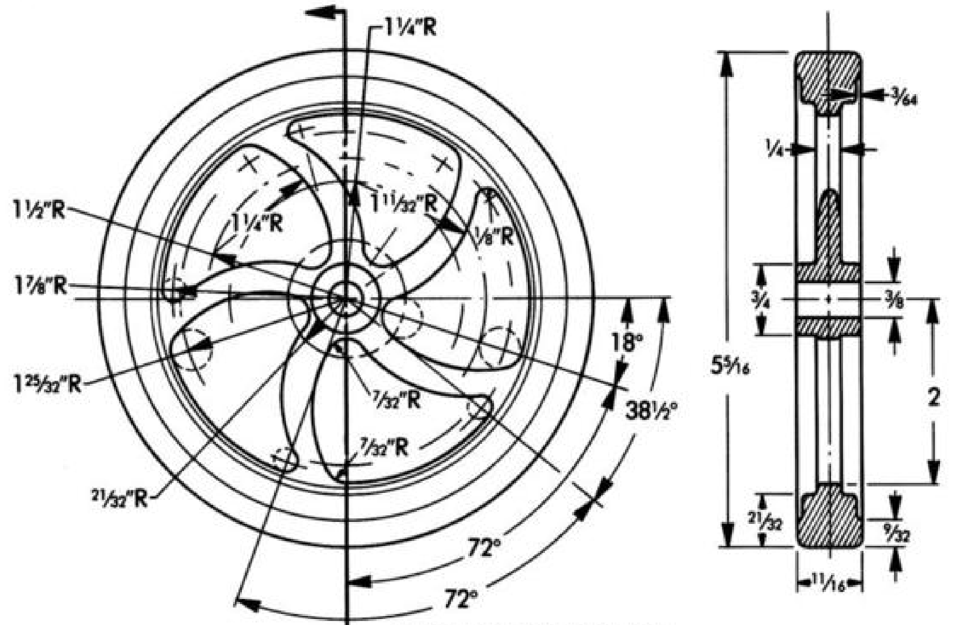
1

In times past, beauty and elegance were often incorporated in an engine's design – and flywheels with gracefully curving spokes were part of that beauty. Even today, curved spoke flywheels will add a touch of class to any motor and will, in fact, eliminate that obvious "homemade" look that often plagues flywheels. Let me share with you one method of machining the curved spokes.

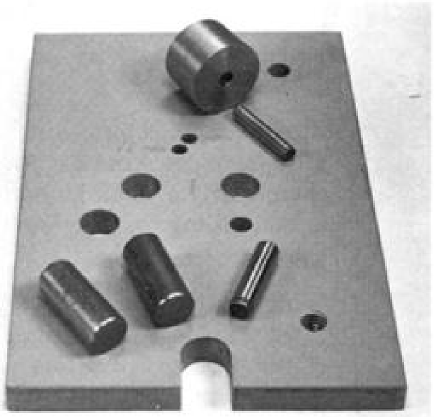
If you have access to a lathe, a vertical milling machine, and a 6" or larger rotary table, it's possible to machine a flywheel like the one in Photo 1. All that's needed are a few easily constructed locating fixtures, and a flywheel blank (machined from a solid disk), and you're ready to begin work on the curved spokes. True, this is a rather slow process, but have you ever purchased a rough-cast iron flywheel, discovered a couple of hidden air holes beneath the rim's surface when you started machining, had to plug them, and then spent days filing and grinding on the rest of the wheel to make it smooth? When you carve out your own flywheel spokes, the milling machine will do 95% of the work for you; there's only a small amount of hand filing to complete the job.

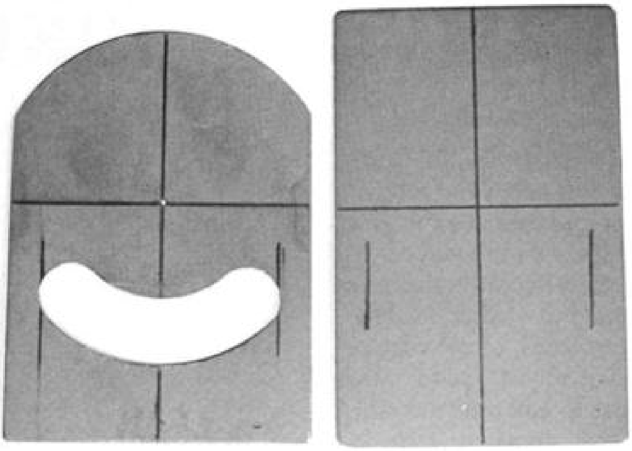
When you first examine the flywheel plan, don't let that confusing array of radius dimensions scare you away! Actually, most of the calculations have already been completed for you. Ease of construction dictated a five-spoke wheel over a six-spoke – yet it doesn't have a sparse appearance as would a three- or four-spoke wheel. Obviously, one may need a flywheel of a different size than this one – simply reduce or enlarge *all* dimensions a specified amount, say 10%, 25%, or whatever. Naturally, the radius template and locating dowel holes in the fixture plate would also have to be altered a corresponding amount.

First, machine your blank to the dimensions shown in the drawing. Then begin work on the Fixture Plate shown in Photo 2, along with the dowel locating pins and the tapered center plug (machine to fit the center hole in your rotary table). Don't worry about the six

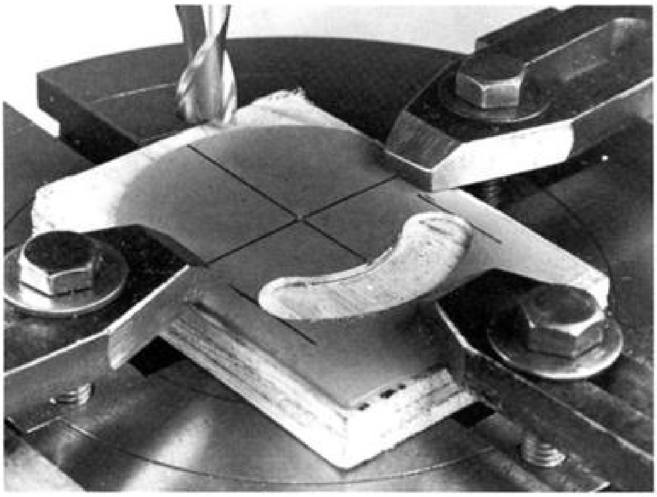


CURVED SPOKE FLYWHEEL
CRS or HRS





2 3



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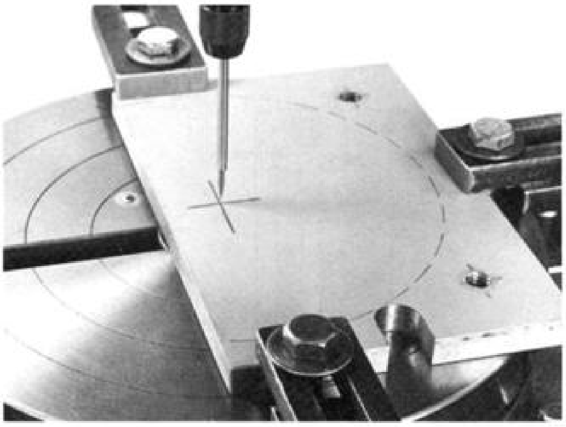

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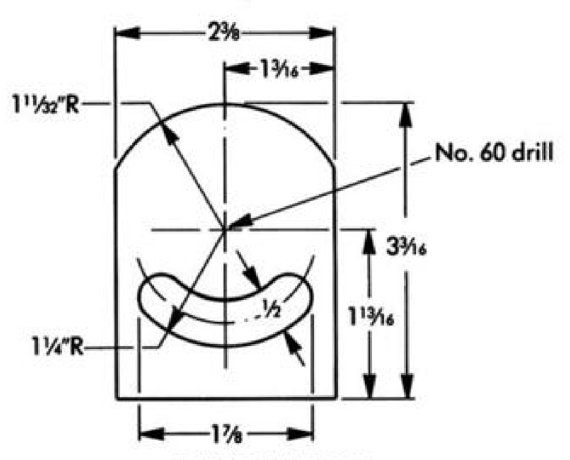
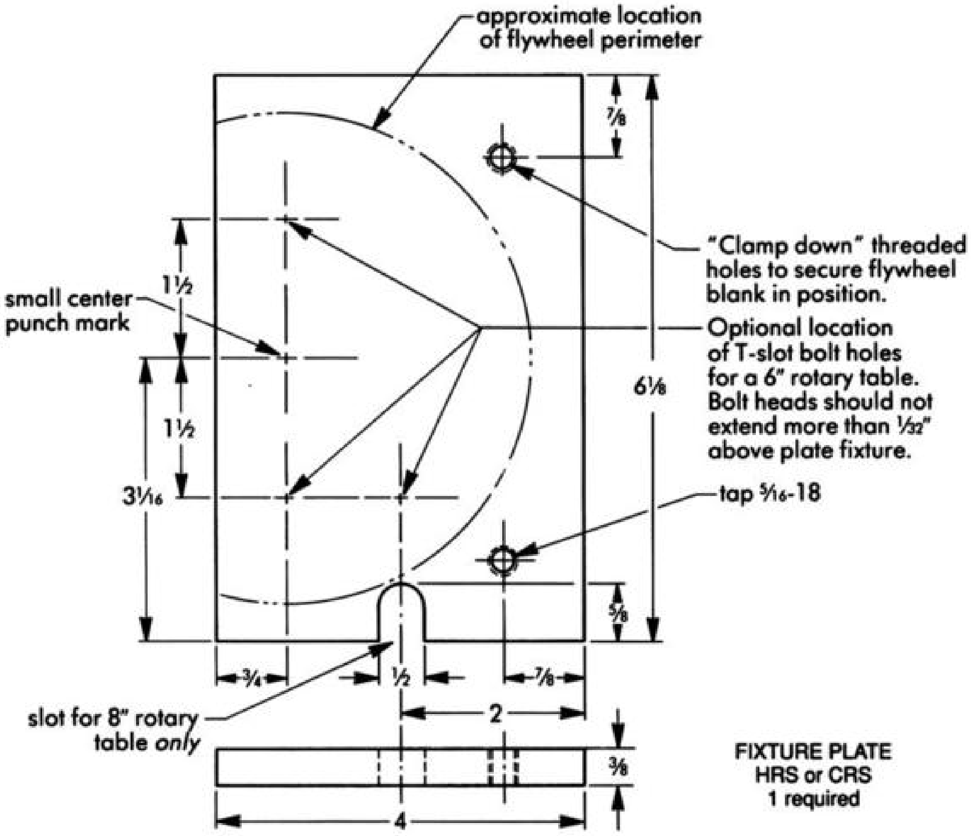
assorted holes located near the central portion of the plate at this time; they'll be dealt with later on. Incidentally, this plate was designed for an 8" rotary table; with a few minor changes (refer to plans) it would be adaptable to a 6" rotary table.

Now make the Radius Template Fixture (Photo 3). The picture is a "before and after" scene. The template *blank* should be slightly longer than the plans call for. To machine the blank, use a dial indicator and perfectly center your rotary table directly below the mill spindle. Lock the mill table both directions and set the calibrated collars of each to zero. Mount the template blank on a flat piece of wood. Position the work so the longest cross center line on the template is fairly well in line with the longitudinal table travel of the mill. Chuck up a "wiggler" in the mill spindle. With loosened hold-down clamps, position the work so the wiggler point is directly over the center of the cross lines; then clamp down the template. Employ a *small* center drill to spot the location and finally drill through with a No. 60 drill. Take note of the degree mark on the rotary table (whatever it may read).



RADIUS TEMPLATE
1 required
Approximate 1⁄16" thick
aluminum or steel sheet metal

Begin work on the 1/2" wide curved slot in the template. With the calibrated collar on the longitudinal table travel set at zero, move the table in the proper direction exactly 1.250",


approximate location of flywheel perimeter
"Clamp down" threaded holes to secure flywheel blank in position.
Optional location of T-slot bolt holes for a 6" rotary table. Bolt heads should not extend more than 1/32" above plate fixture.
tap 5/16-18
small center punch mark
7/8
6 1/8
1 1/2
1 1/2
3 1/16
5/8
3/4
1/2
7/8
2
3/8
4
slot for 8" rotary table *only*
FIXTURE PLATE
HRS or CRS
1 required

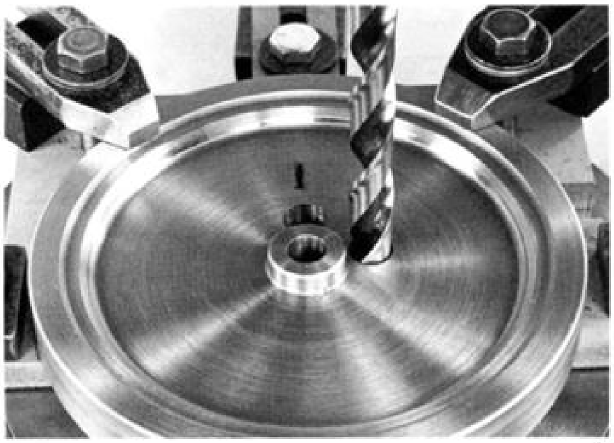
minus one half the actual diameter of your 1/2" end mill. With the aid of the rotary table, the curved slot is formed by a *gradual* lowering of the mill cutter. The length of the slot is not critical. Now return the mill table to the original zero setting. Revolve the rotary table back to the *original* degree mark that you noted. Now, in order to mill the radius on the end of the template, revolve the table 180° from that mark. Again move the mill table in the same direction as before, but this time to the distance of 1.344" *plus* half the actual diameter of your end mill cutter – a small diameter end mill, perhaps 3/16", is preferable. If you use a 1/2" end mill as I did, gradually lower the cutter as you crank the rotary table (Photo 4); heavy cuts may cause the end mill to catch and bend the thin template.

To begin actual work on the spokes of the flywheel: once more, accurately center the rotary table beneath the mill spindle. Set the longitudinal table calibrated collar to zero. Place the fixture plate on the rotary table as in Photo 5, but do not tighten the hold-down clamps. Have the rotary table degree marks set exactly at zero and lock it. Adjust the position of the fixture plate so its longest sides are approximately at right angles to the longitudinal travel of the table. Now slide the fixture plate until the wiggler point is directly above the cross lines on the fixture plate; then tighten the hold-down clamps. Lock the mill table both directions.

We are now ready to drill holes in the flywheel blank, but at this point it might be advisable to substitute a round disk of 1/2" plywood approximately the diameter of the flywheel to practice on until the hole drilling procedure is clear in your mind. Remember, you've already spent a lot of time machining the wheel blank, so to ruin it now by drilling some of the holes in the wrong places would be a disaster! If you decide to practice on a wood disk, the procedure will be the same as the real thing except to drill all of the holes only about halfway through the wood; all we are concerned with now is to drill the holes in the *correct location.* After drilling, they should be measured to verify that *all* holes are in the proper location.

For drilling the holes in the real flywheel, leave the hold-down clamps loose on the flywheel (Photo 6). Carefully shift the flywheel by hand until its center hole is *perfectly* lined up with the spindle center of the mill. Then tighten the hold-

6



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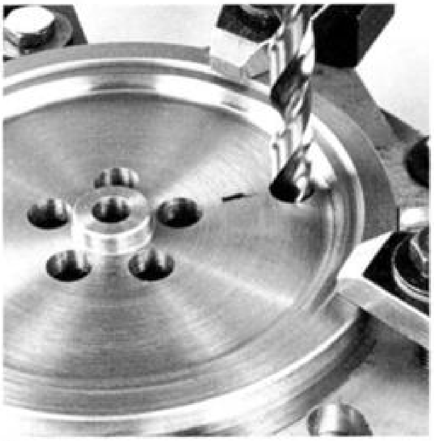

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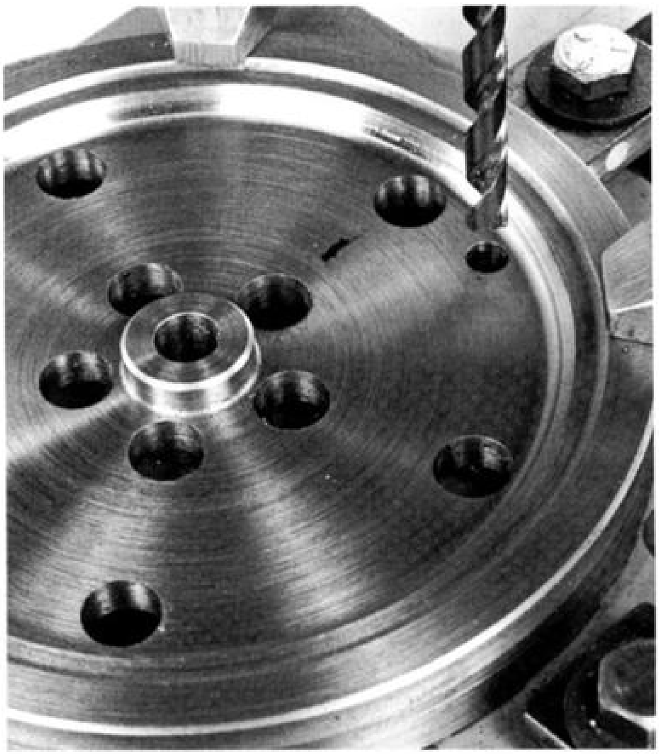
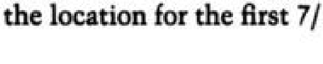


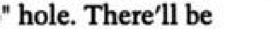
9

down clamps; unlock the longitudinal table, then move the table to the left *exactly* 21/32" from the zero setting; this will position the mill spindle on the right-hand side of the flywheel hub. Chuck up a center drill and spot the location for the first 7/16" hole. There'll be five holes drilled around the hub. Now, the first two holes will not only be drilled through the workpiece but also down into the fixture plate to within 1/32" of going all the way through (Photo 7); so set your spindle stop accordingly. We don't want to drill surplus holes into the rotary table! I prefer using a 3/16" drill for a pilot hole, then following with a 27/64" drill, and finally, the 7/16". Use cutting oil to help eliminate an oversize hole – or if you prefer, you could ream the 7/16" hole.

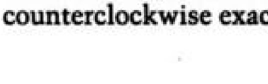
Remember, the first and second holes are drilled through the work and also *into* the fixture plate beneath. After completing the first hole, revolve the rotary table in a counterclockwise direction exactly 72° and lock it in place. Now drill the second hole. This new setting should place your pointer on the rotary table at the 288° mark. As you proceed, write down each new 72° setting on paper for future reference. The three remaining holes are drilled through the flywheel only. Then revolve the rotary table back to the original zero setting. Return the longitudinal table to its original zero setting on the calibrated collar. Now move the mill table to the left *exactly* 1-25/32" and prepare to drill the first outer hole (Photo 8). Only this *first* outer 7/16" hole will be drilled down into the baseplate. Now index the rotary table counterclockwise exactly 72°, as before.



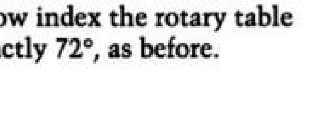
DOWEL PIN
steel
2 required



DOWEL PIN
steel
1 required

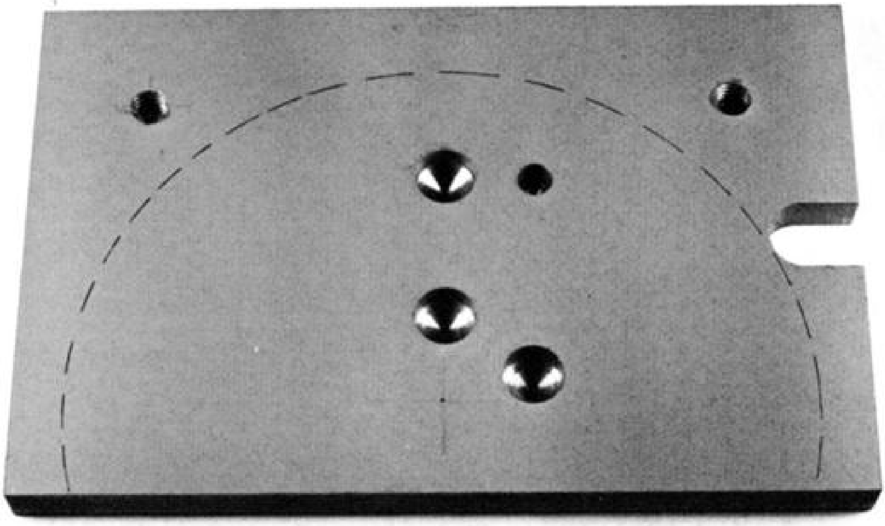


DOWEL PIN
steel
1 required



Machine center plug to fit your rotary table center hole.

CENTER PLUG
CRS
1 required



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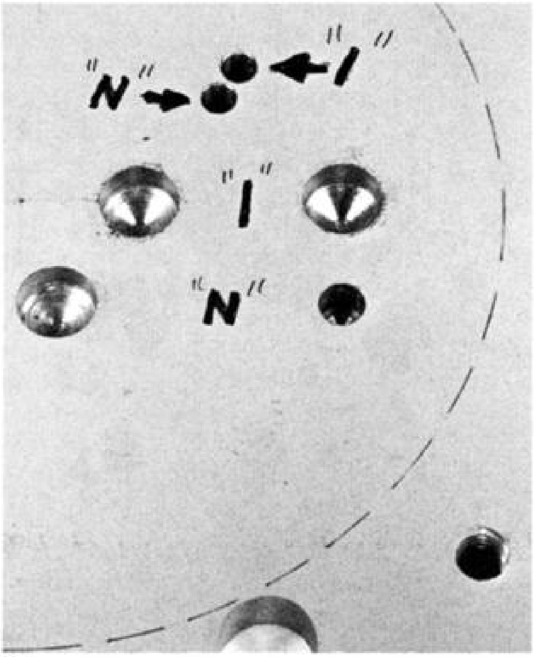

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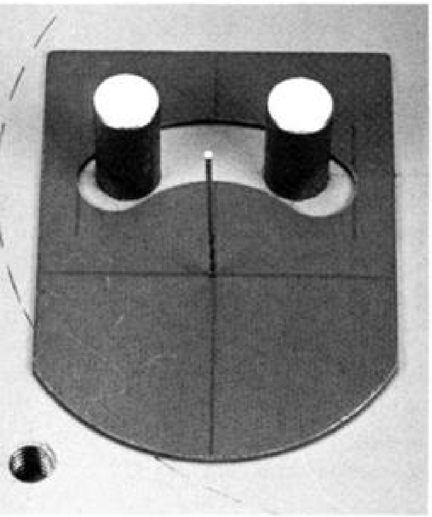
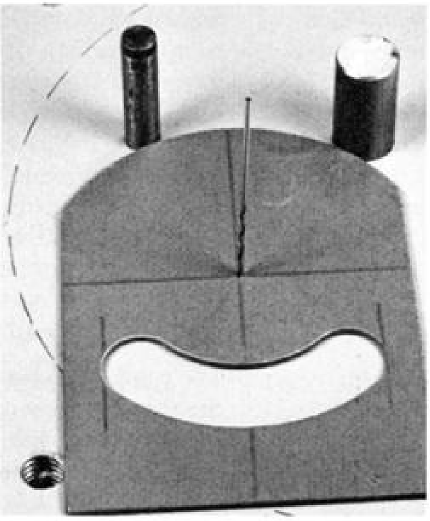
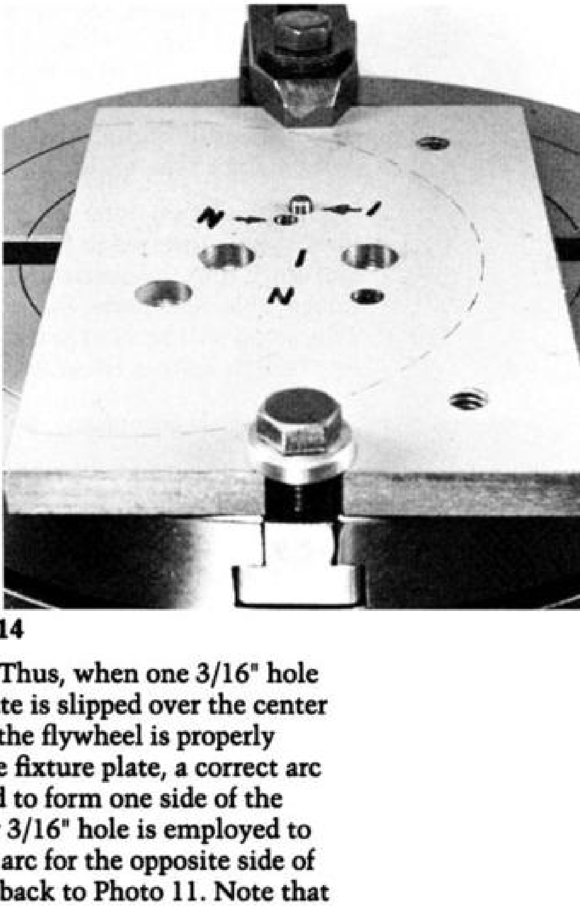




12 13



14

Repeat the procedure on the four remaining holes, but only through the flywheel itself. Upon completion, rotate the rotary table back to the zero degree mark. Return the mill table to its original zero mark. Now move the table to the left *exactly* 1-7/8". Revolve the rotary table counterclockwise *exactly* 20-1/2° and lock it (Photo 9). Only this first 1/4" hole will be drilled through the flywheel and also into the base fixture. After drilling, rotate the rotary table counterclockwise exactly 72° from the first hole setting. Double check the degree marks. Repeat this process for the remaining holes. Remove the flywheel and then the fixture plate from the rotary table; the plate should appear as in Photo 10.

The next step is to locate and drill the two 3/16" "center lineup" holes in the fixture plate (Photo 11). Their purpose is to position the fixture plate exactly on the true center line of the rotary table. Thus, when one 3/16" hole in the fixture plate is slipped over the center locating pin and the flywheel is properly positioned on the fixture plate, a correct arc will be machined to form one side of the spoke. The other 3/16" hole is employed to form the correct arc for the opposite side of the spoke. Refer back to Photo 11. Note that the two 3/16" holes are located *above* the four original holes (as seen from the mill operator's point of view).

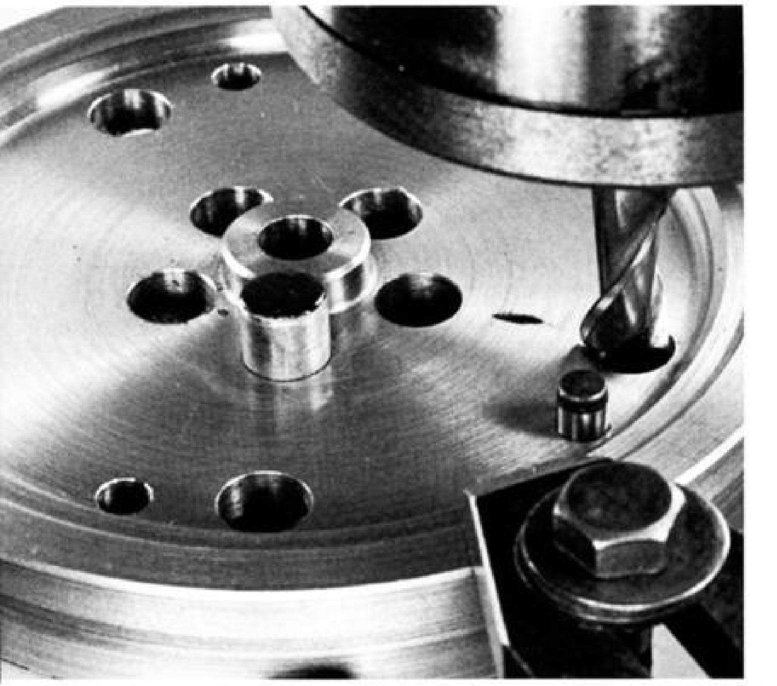
Now, to find the correct location for these two holes, the radius template is brought into use. Examine Photos 12 and 13. For photographic purposes these two pictures were taken from a position 180° opposite that of Photo 11, hence the illusion that we are spotting the location of the two 3/16" holes below the four original holes – not so! We'll spot the location of the first hole as in Photo 12. Insert the two 7/16" dowel pins in the two holes that are farthest apart in the fixture plate. Slip the slotted radius template over the pins and hold the template so its *outer* curved rim is in contact with the two dowels. Insert a No. 60 drill into the previously drilled center hole and twist it with your fingers to spot the fixture below. Remove the template and check to see if the small point mark is visible. If not, you may have to paint this area a light color to see the drill point mark clearly.

Next, remove the two 7/16" dowels and insert one of them into the remaining 7/16" hole. The 1/4" dowel is inserted in the 1/4" hole. Place the template (Photo 13) with its convex curve against the two dowel pins; again spot the location by twisting the No. 60 drill in its hole. For accurate drilling of these two 3/16" holes, it's best to do the job in your milling machine. Use a wiggler or center scope to center the mill spindle directly over the drill point spots on the fixture plate.

Upon completion, refer to Photo 14. The 3/16" dowel pin is inserted in the number "1" hole and down into the center plug hole in the rotary table. Secure the fixture to the table. This setup will be used to form an arc on the flywheel to mate between the two 7/16" holes with the "1" between them. Now, lay the flywheel on the fixture plate (Photo 15). Insert the 7/16" dowel pin and the 1/4" dowel pin through the flywheel and into their respective holes in the fixture plate – that is, the two holes with the "N" between them (Photo 14). Clamp the flywheel firmly to the fixture plate. Insert a *sharp* 7/16" end mill in the spindle and position it as in Photo 15. The curved slot about to be milled through the flywheel will form the concave arc on one side of the spoke.

When an end mill is employed to mill a rather deep slot such as this one, chips will collect in the slot and the revolving cutter will bang them against the sides. Since we don't desire a roughly finished surface on the sides of the spokes, position the end mill about 1/64" *away* from where the finished curve will be. Now lock the mill table both directions. The rotary table is employed to form the arc. Don't attempt to mill through the flywheel in one or two swipes. Lower the end mill about .030" or .040" at a time as you cut down between the two holes. Don't allow the end mill to touch the 7/32" radius at each end of the slot. Once through the metal, it's time to finish the concave side of the spoke; slightly advance the end mill toward that surface and carefully mill until the wall of the spoke blends into the 7/32" radius at each end.

The completed slot is shown in Photo 16. Notice the rough wall caused by chip interference on the *unwanted* side of the slot. Now loosen the clamps holding the work, remove the two



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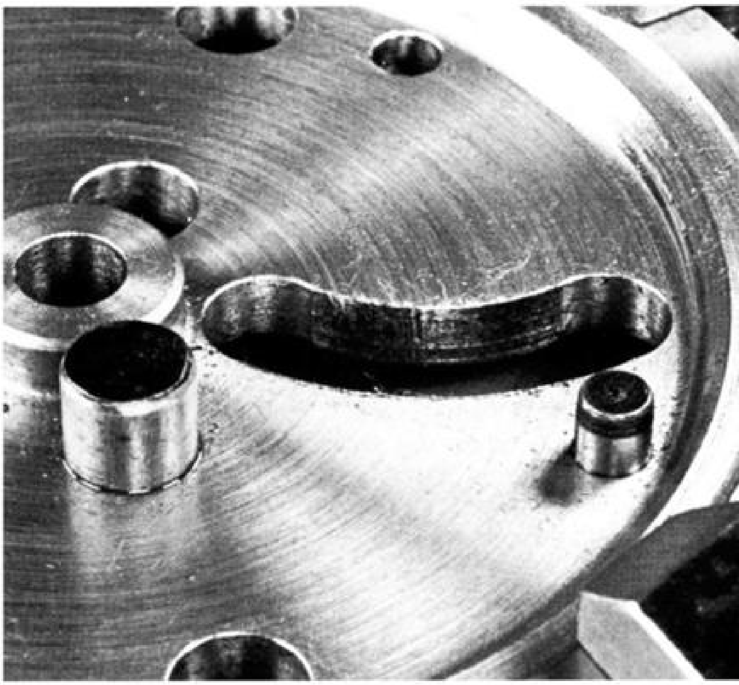
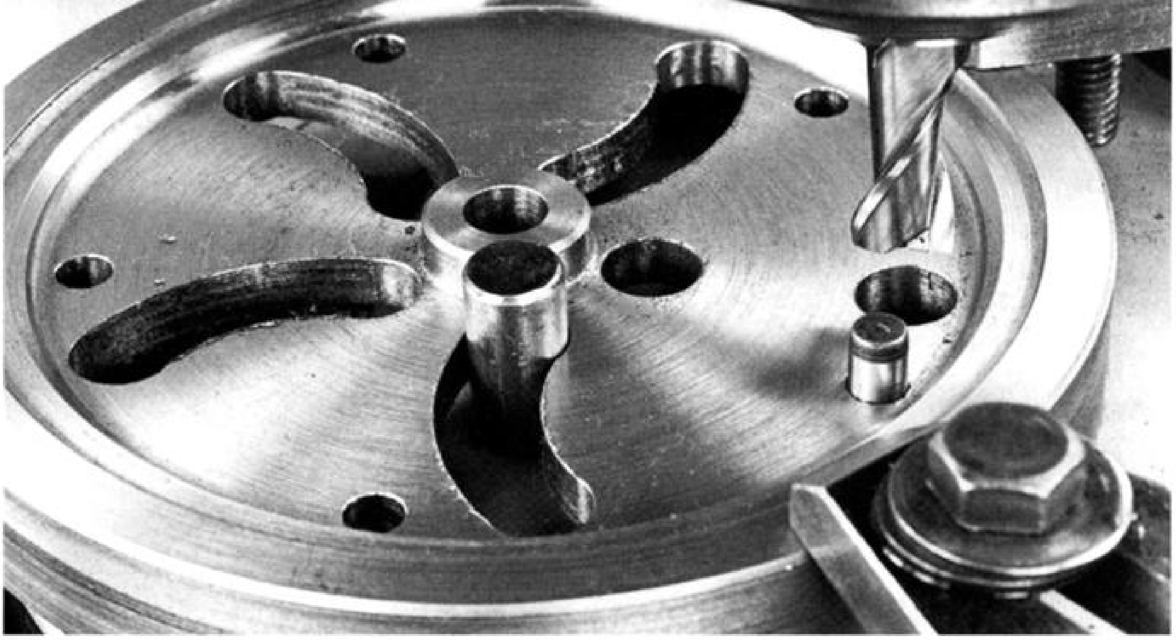
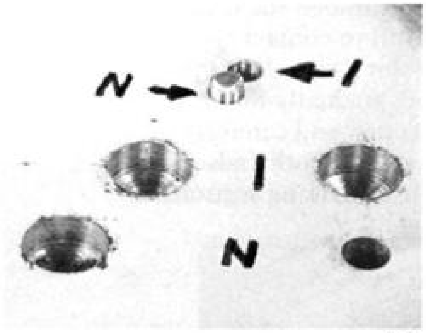


16



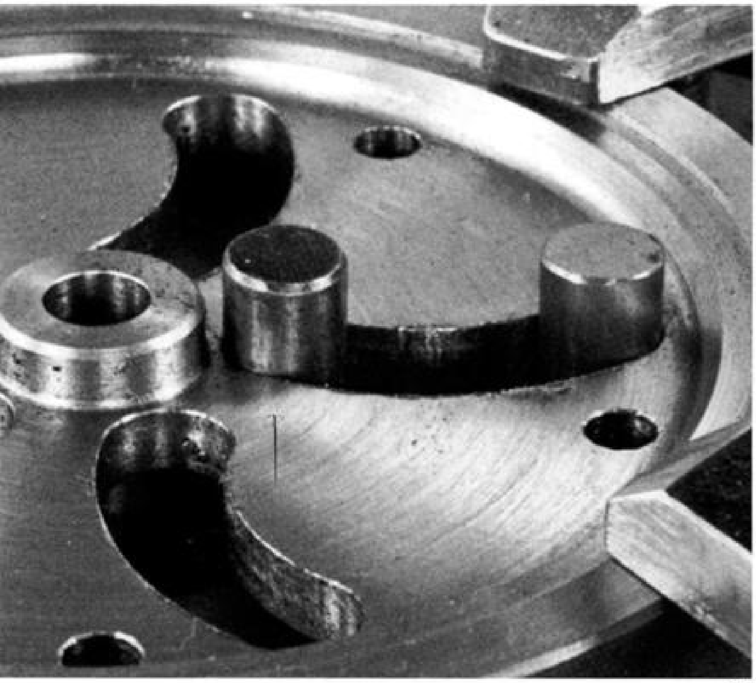
17

dowels, and rotate the flywheel, by hand, to the next position. Reinsert the two pins through the flywheel and into the base fixture holes. Clamp the work down and proceed as before. Photo 17 shows the setup for the fifth slot.



18

When finished, remove the flywheel and then the fixture plate. Clean everything and place the fixture plate back on the table. This time insert the 3/16" dowel into the "N" hole (Photo 18), and down into the center plug hole in the rotary table. Clamp the fixture plate to the rotary table. Insert the two 7/16" dowels through the flywheel slots and down into their respective holes in the plate (Photo 19). Clamp the work down as before. This setup will form the convex side of each spoke (Photo 20). Notice that a *sharp* 1/4" end mill is now employed because the radius at the outer end on this side of the spoke is a 1/8" radius. Again, position the end mill about 1/64" away from where the finished side of the spoke should be. Don't allow the cutter to touch the radius at either end of the slot. Mill down gradually as before. To cut the remaining slots, repeat the whole procedure until the curved spokes are all finally visible!



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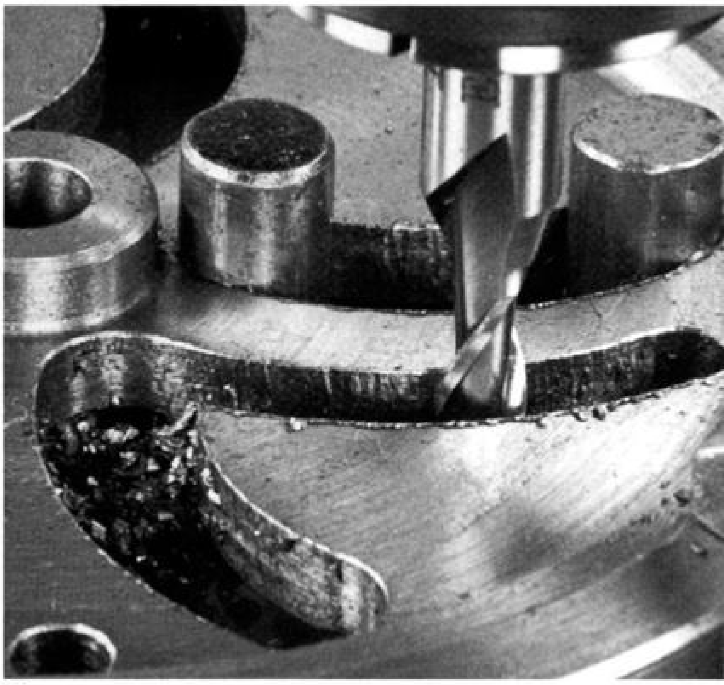

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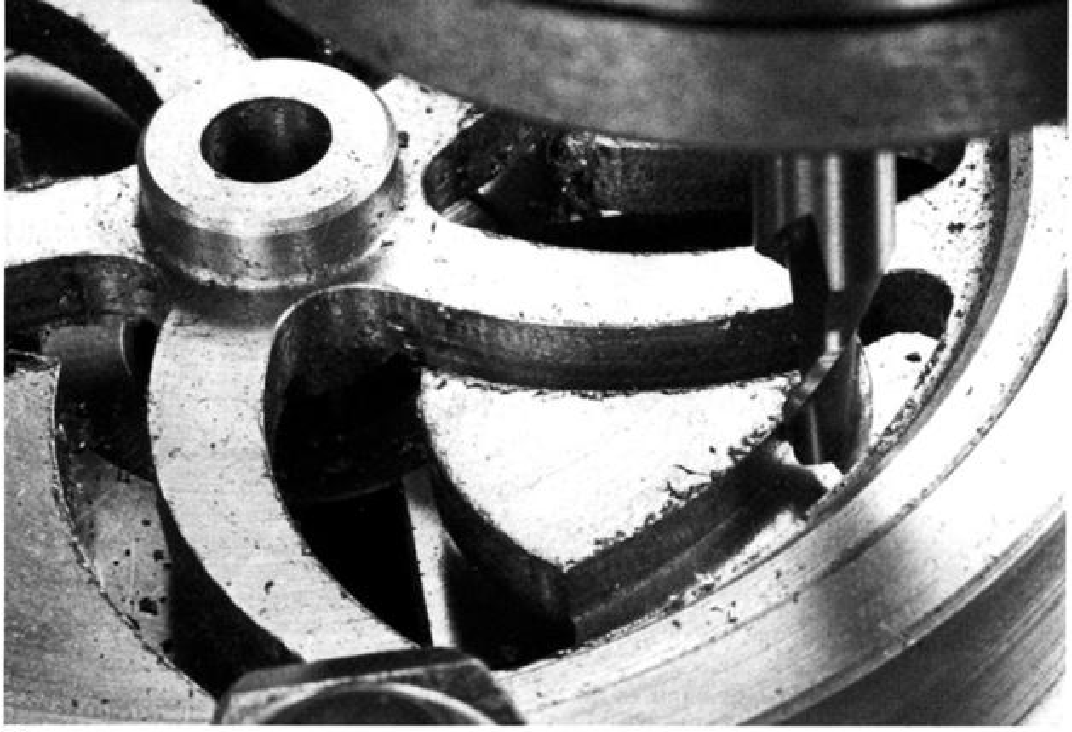
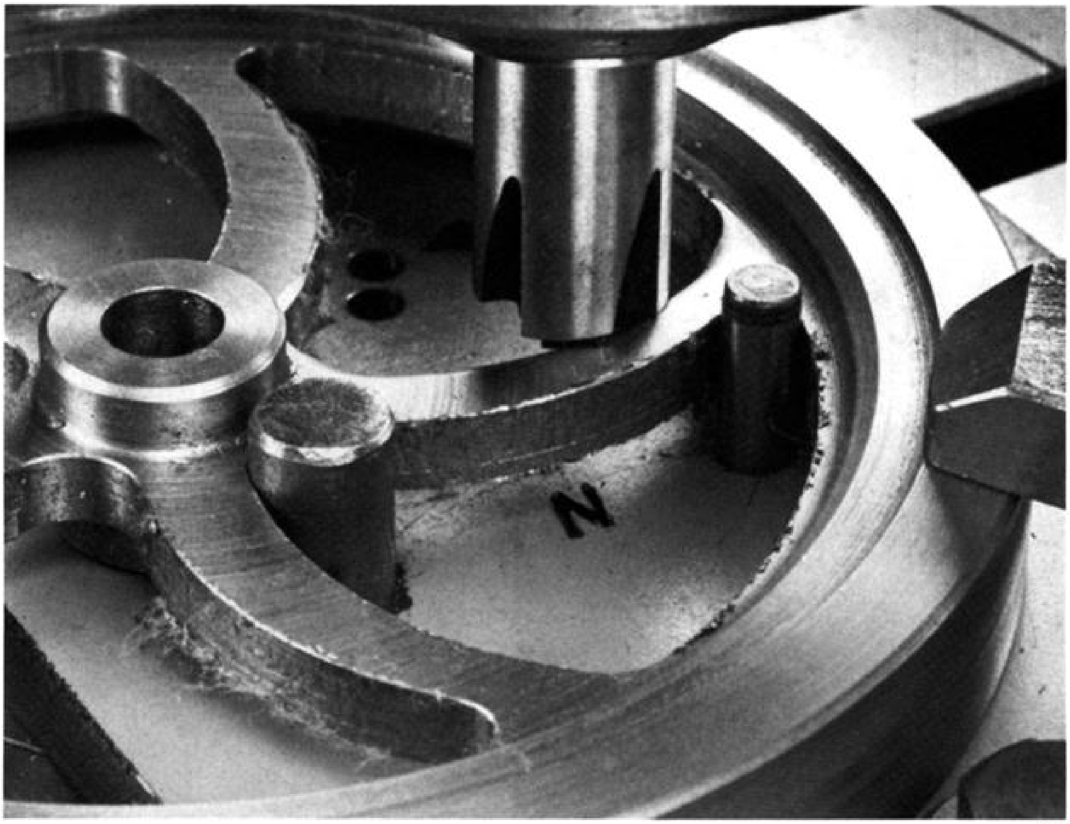


21

Remove the flywheel, then the fixture plate, and set it aside. Remove the center plug from the rotary table and reposition the center of the table accurately beneath the mill spindle. Then place the flywheel on the rotary table and accurately center it; firmly clamp it in place. Position the 1/4" end mill (Photo 21), for cutting the curved slot close to the inner rim of the flywheel. Again, keep the slot about 1/64" away from where the finished inside portion of the flywheel rim will be. Use the rotary crank to mill down through the metal, but don't allow the end mill to contact the radius at each end of the slot. Once the surplus piece of metal is removed, gradually move the cutter in an outward direction and carefully blend the rim arc to the radii at both ends. Repeat the process for the remaining sections.



22

There are two options open for you to finish the flywheel. The sharp edges on the flywheel spokes can be rounded off by hand with a file, or they can be machined off with a 1/8" radius corner rounding end mill. If you prefer the latter method, then reinstall the center hole plug into the rotary table and position the fixture plate on the rotary table. Once more insert the 3/16" dowel pin into the number "1" hole in the fixture plate and also down into the center plug hole. Clamp down the fixture plate. Use the 7/16" and 1/4" dowels and position the flywheel so that the two pins are touching their respective spoke radius (Photo 22). Clamp down the work. Now cautiously move the cutter to contact the edge of the spoke. With the aid of the rotary crank, gradually begin rounding off the sharp edge along the spoke. Don't allow the outer diameter of the cutter to dig into the inner rim *or* the hub portion of the flywheel. Don't attempt to utilize the full capacity of the cutter; if the cutter is lowered too far or moved in sideways excessively, it will cut a nice little unwanted step along the spoke – and you'll find yourself either filling it in or filing it off!

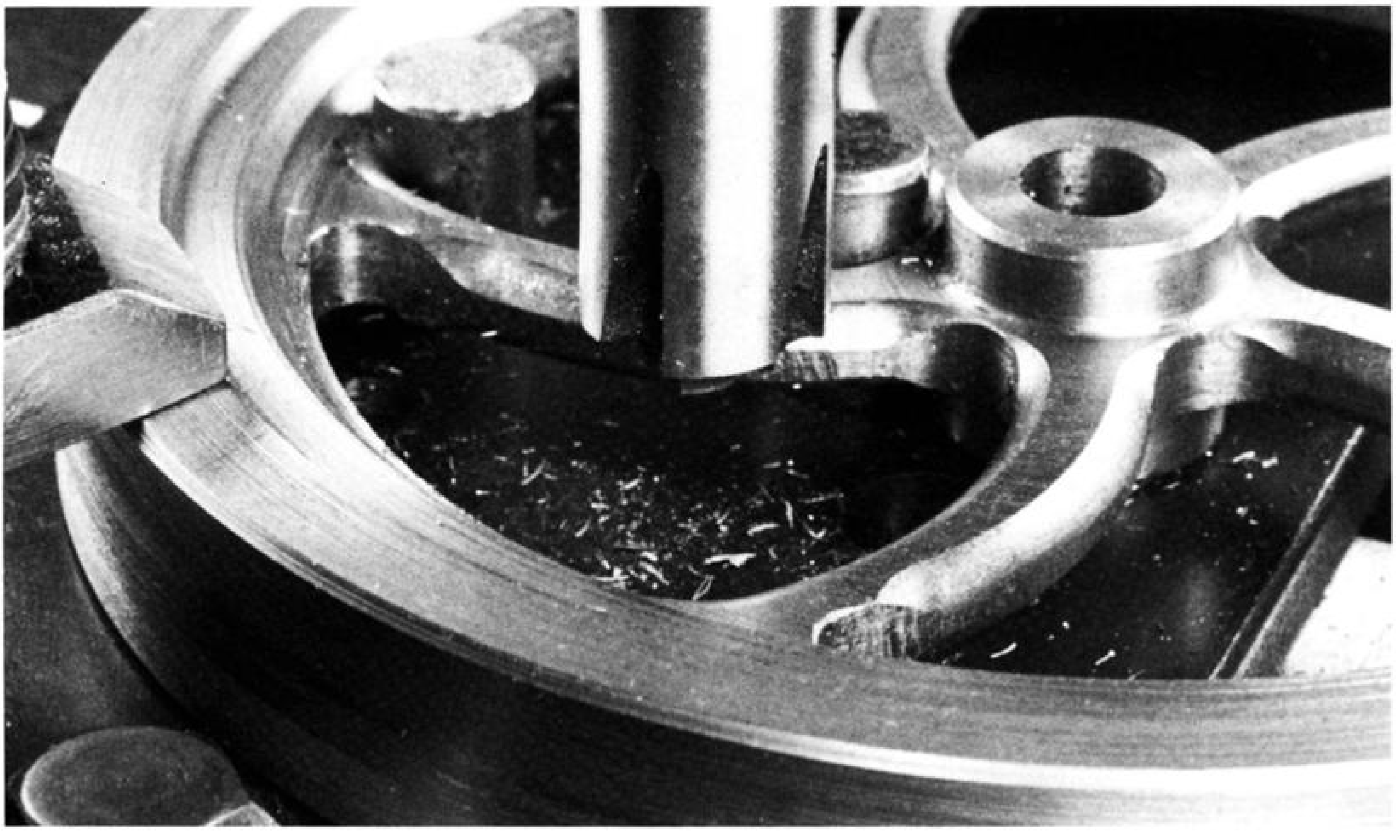
When all five spokes are rounded on that edge, remove the flywheel and relocate the fixture plate by inserting the 3/16" dowel into the "N" hole on the plate and down into the center plug hole. Install the two 7/16" dowels in their place against the side of the spokes that were just rounded off. Clamp down the flywheel and proceed to mill the other side of each spoke.

When finished, it's necessary to turn the flywheel upside down to machine the spokes on the other side. The fixture plate must be removed from the rotary table and the four "dead end" holes in it are then drilled all the way through the plate. Now place the fixture plate upside down on the rotary table (Photo 23). As visible in the last photo, it's impossible to round off the spokes all the way to the inner rim of the flywheel. This small portion will have to be filed by hand.

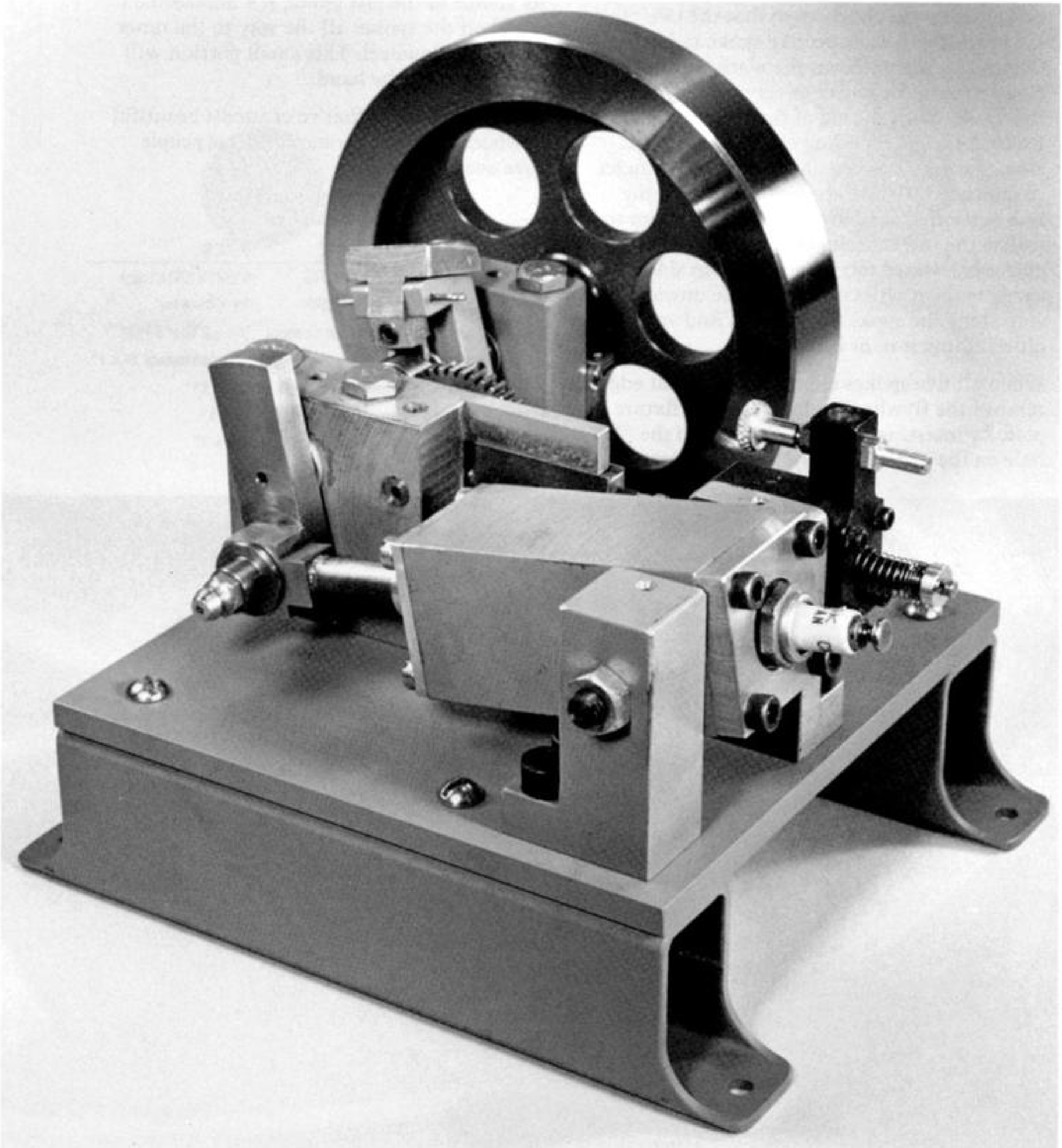
There you have it! You've created a beautiful flywheel, and that's something few people have accomplished!

BILL OF MATERIALS
(finished sizes)

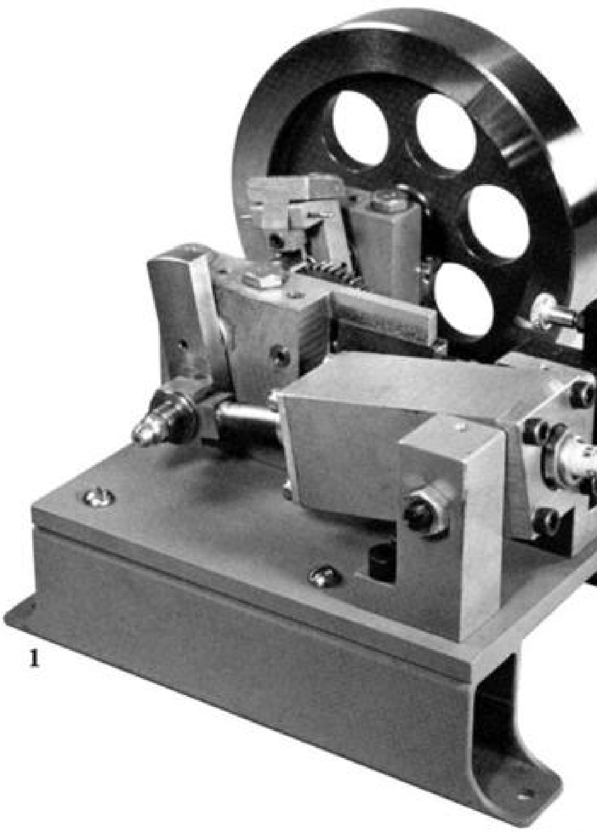
NO. OFF	MATERIAL	SIZES
1 Flywheel blank	HRS or CRS	1 1/16" × 5 5/16" disk
1 Fixture plate	HRS or CRS	3/8 × 4 × 6 1/8"
1 Radius template	aluminum or steel	1/16 × 2 3/8 × 3 3/16"
1 Center plug		approximately 1/4 × 1"
2 Dowel pins	steel	7/16 × 1"
1 Dowel pin		1/4 × 1"
1 Dowel pin		3/16 × 1"


23

"Whatzit" Engine



Most readers of this publication are probably familiar with the oscillating steam engine, a quaintly unique motor with a cylinder that pivots back and forth as the crankshaft revolves. Okay – so you are forgiven for assuming that the little contrivance in Photos 1, 2, and 3 is such an engine – it's an oscillating *gasoline* motor! Now, who ever heard of an oscillating gas engine? Well, I understand that several different types were made during the latter part of the 19th century. So, I thought it would be a nice challenge to design and build such a motor.
It turned out to be a fun project! It's a guaranteed conversation piece. People stand in mesmerized disbelief when seeing the cylinder wobble vigorously in time with the churning crankshaft.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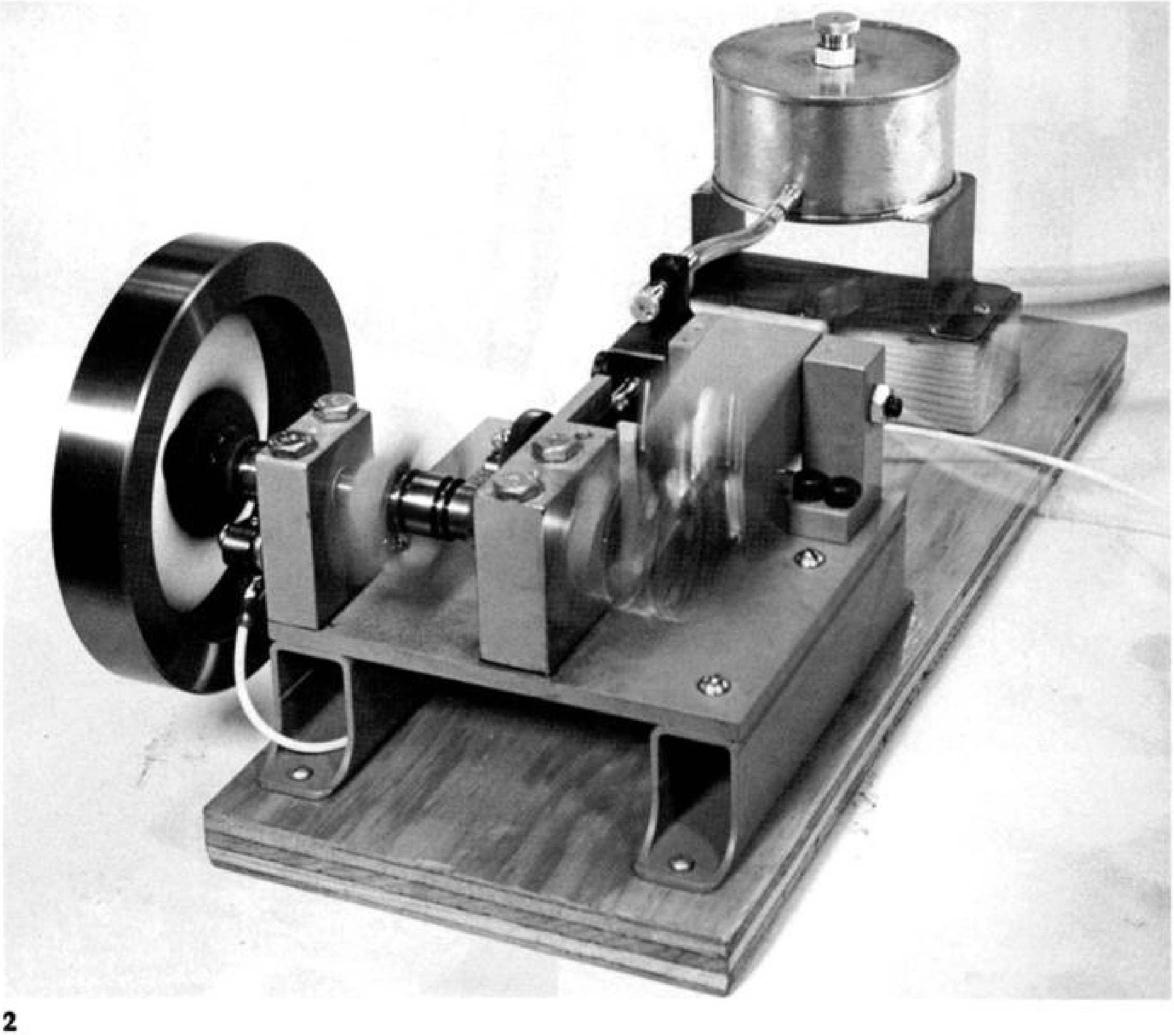
The engine is very simple; no welding or castings are required for its construction. It's a 1" bore four-cycle "hit and miss"- type motor fabricated mainly from scrap blocks of steel. There's a single flywheel and a simple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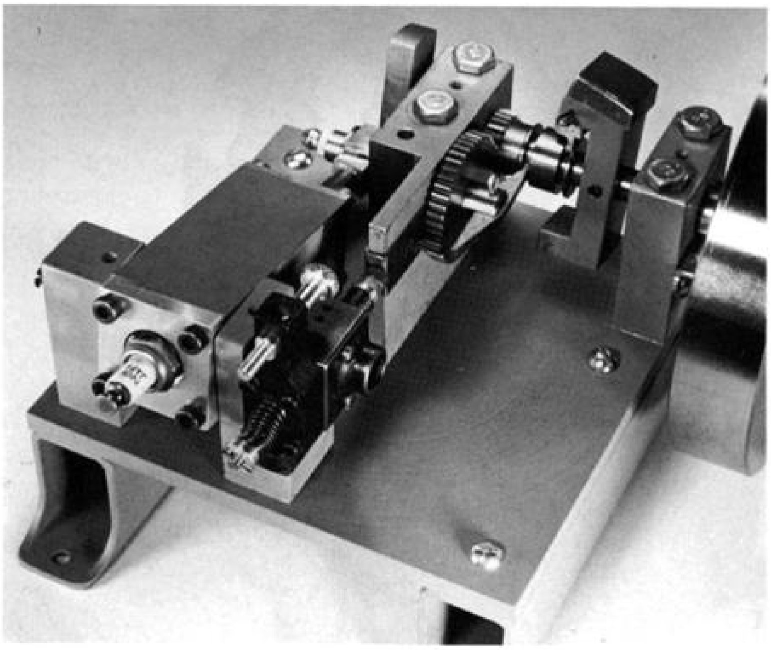
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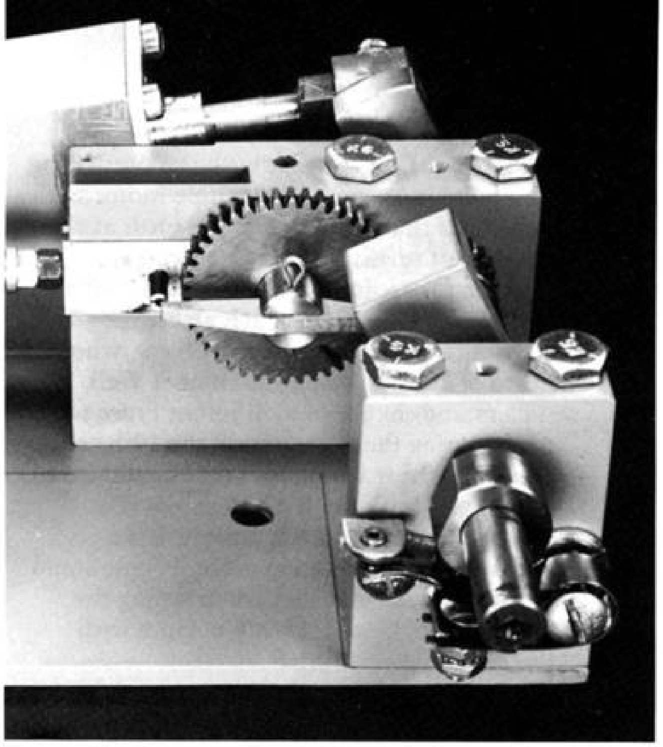
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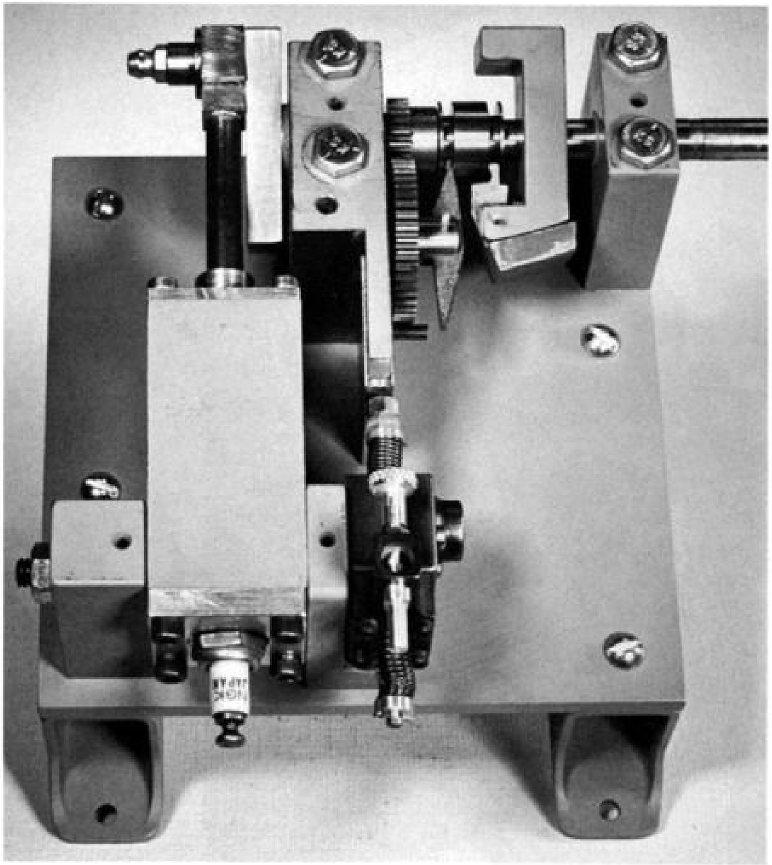
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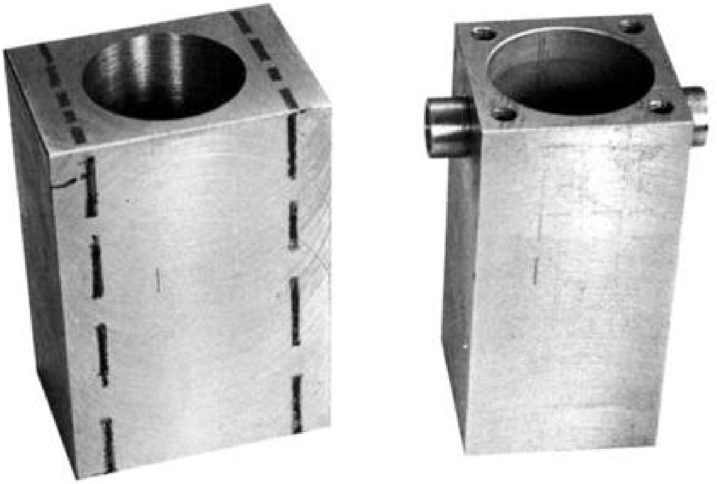
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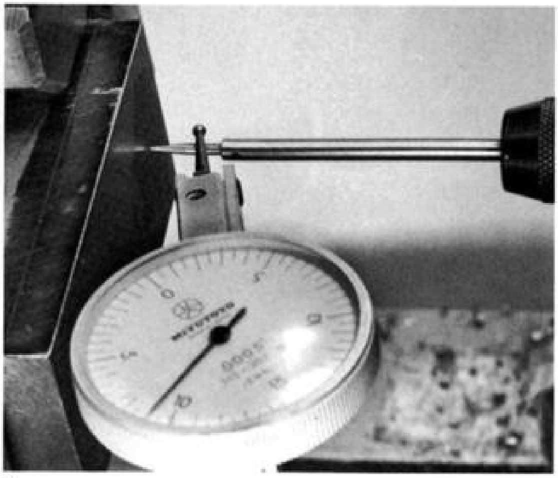
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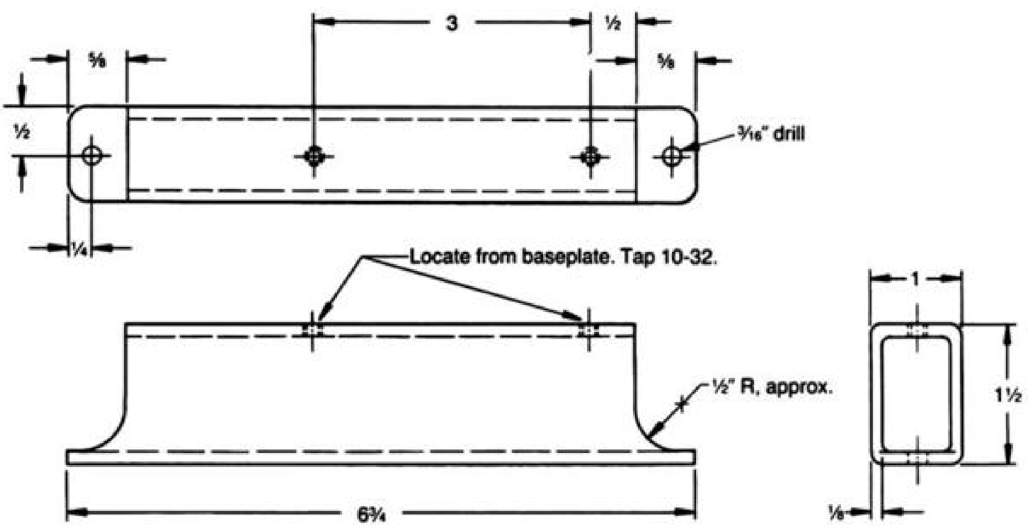
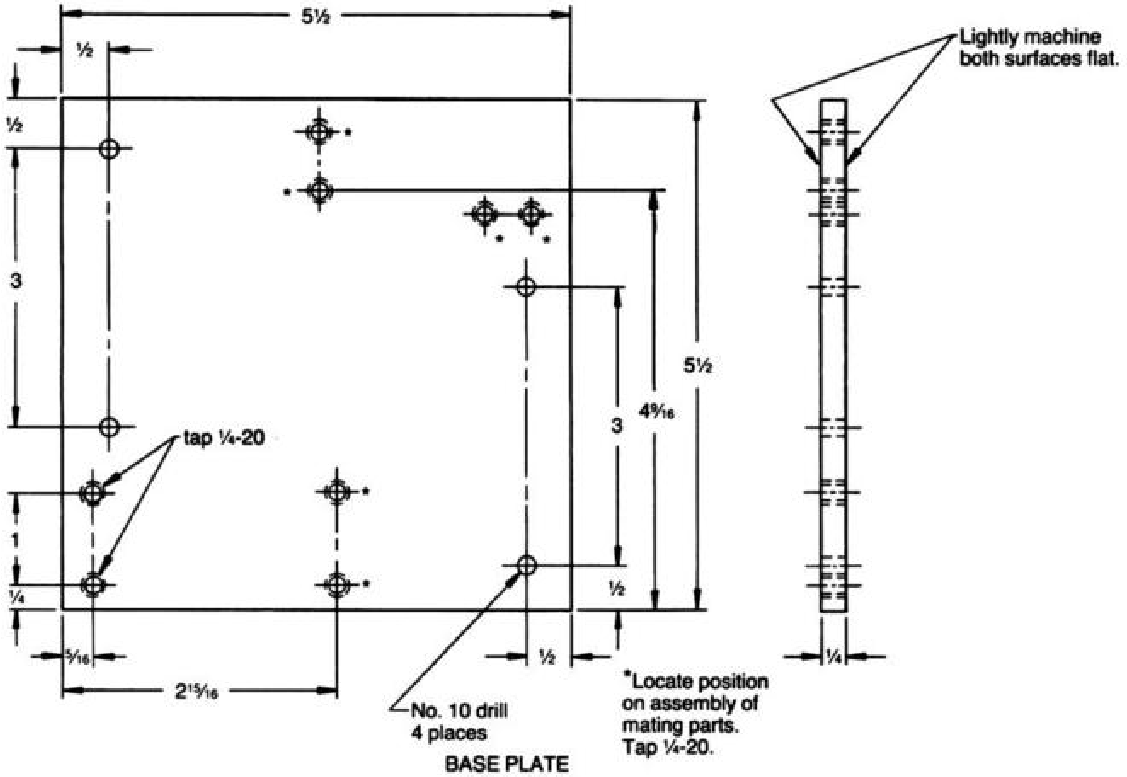


BASE LEGS
HRS rectangular tubing
2 required



Lightly machine both surfaces flat.

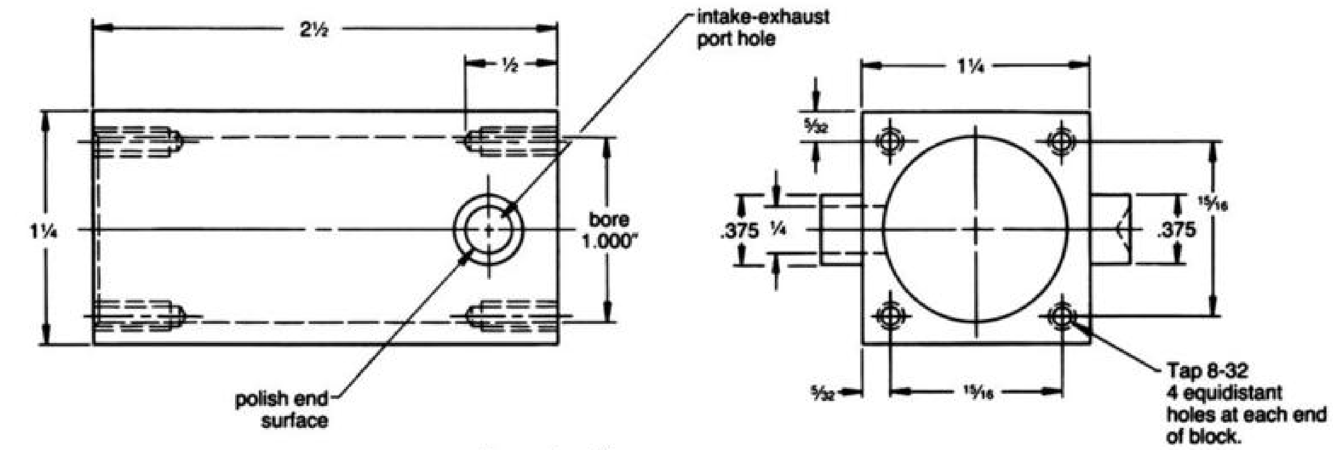
No. 10 drill
4 places

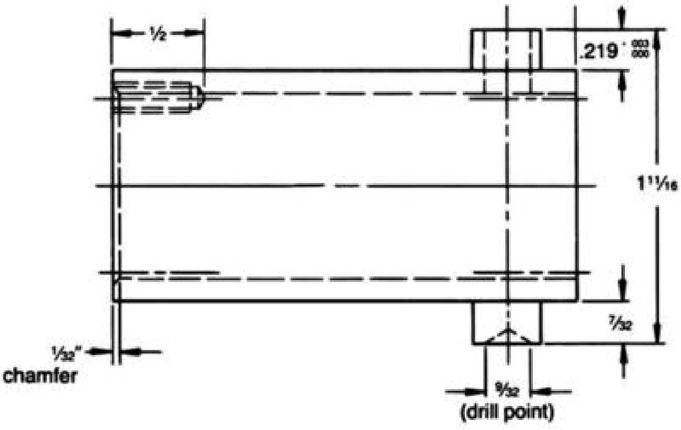
*Locate position on assembly of mating parts. Tap ¼-20.

BASE PLATE
HRS or CRS
1 required

open-end crankshaft. The "air-cooled" cylinder block is void of cooling fins. To lessen the chance of overheating, a governor mechanism allows the motor to perform admirably under a no-load condition.

Both *intake* and *exhaust* for the cylinder is accomplished by means of a hole through one of the cylinder pivot shafts. This shaft is held in a support column to which the combination carburetor-exhaust unit is bolted. Basically, this carburetor-exhaust unit is a simple mechanism, with the intake valve being activated by suction from the cylinder; in Photo 4, the stem of this valve, with its spring, is visible protruding from the back of the carburetor section; on the opposite side is the exhaust valve. Next are the push "rod" and timing gears. The governor is on the main crankshaft. Finally, in Photo 5, the ignition is visible.





CYLINDER BLOCK
HRS or CRS or cast iron
1 required

Begin work on the Baseplate and Legs. It's advisable to lightly machine both sides of the plate to assure perfect flatness. Most of the motor's main components are also machined from blocks of steel; they, too, should be brought down to the size of that particular part – all sides of each piece *square* to one another. Apply layout blueing and scribe cross lines for holes or lines for further machining, etc. Make all of the main body parts *before* mounting anything to the baseplate.

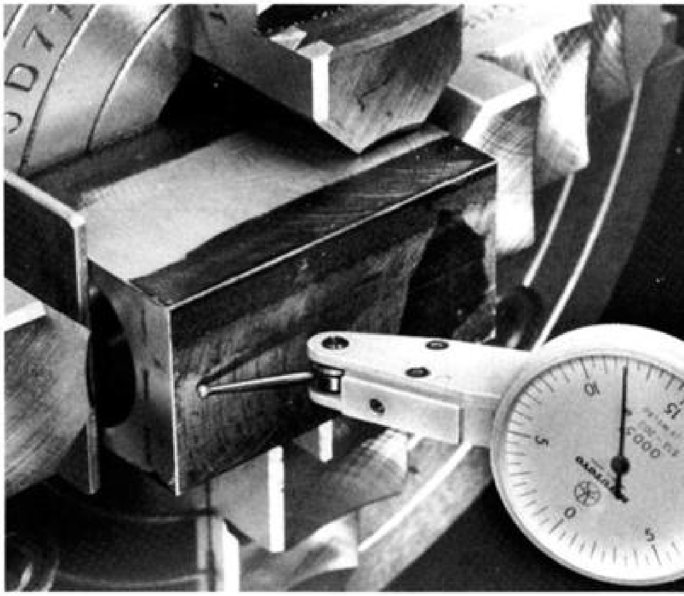
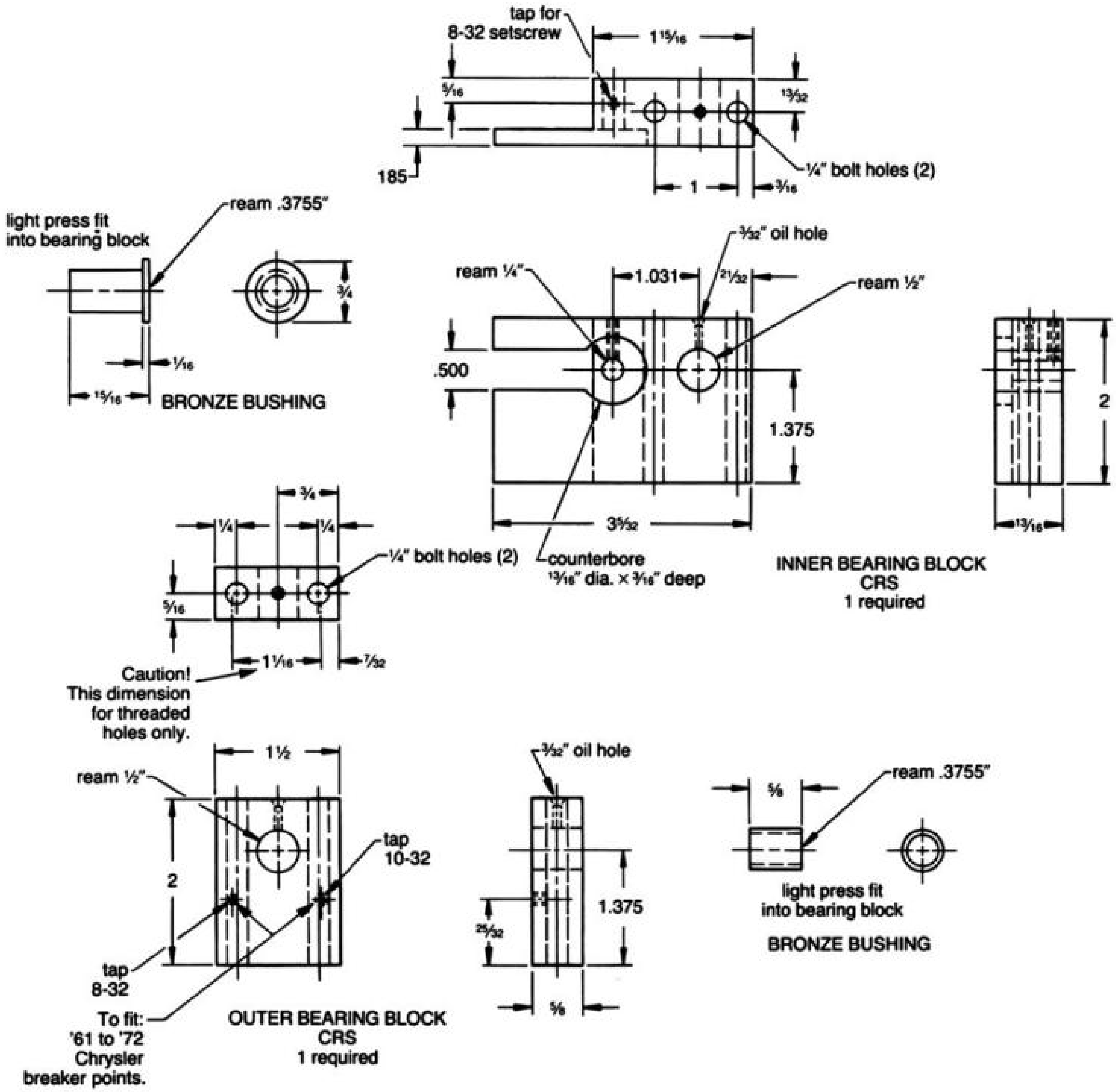
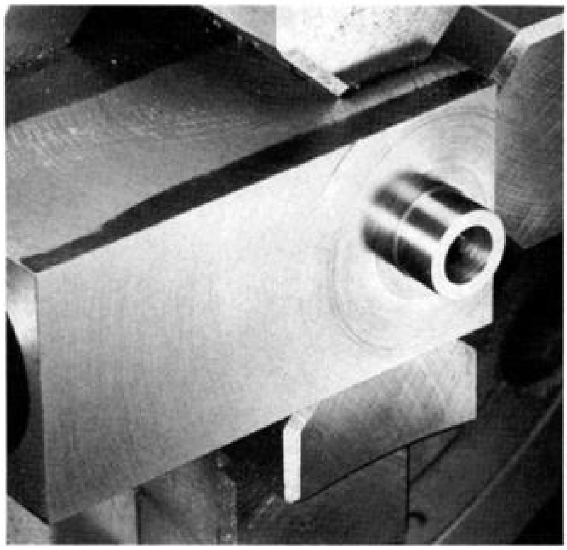

8

Photo 6 illustrates two stages in making the Cylinder Block. The block on the left has been squared and its sides made parallel to each other; the cylinder hole has been drilled and bored to size. Now carefully lay out and scribe the center lines for the two pivot shafts. The easiest method of centering cross lines in a lathe is with an optical center scope attached to the tailstock – otherwise, use a sharp, narrow, pointed instrument, such as an ordinary metal scriber, to pin prick the center of the pivot cross lines. Don't use a center punch; their points are too blunt. Use a magnifying glass to see where you're actually placing the scriber point. When positioned correctly, press down firmly to produce a small indentation in the metal. Now mount the workpiece in a four-jaw chuck for machining (Photo 7). With the aid of a "wiggler" held in the tailstock and a dial indicator, as shown in Photo 7, a quite accurate centering is possible. Then, as in Photo 8, use the cross slide to run the indicator along the face of the work; adjust the block to a zero reading. Now go back to the setup as in Photo 7 and double check the center mark; machine as in Photo 9. This is the port hole side of the block. Remove the block from the chuck and reinstall with its opposite side outward. Repeat the centering up procedure and machine the pivot journal. Now, with a 9/32" drill, make a dimple in the end of the pivot. This forms a seat for the adjusting ball.

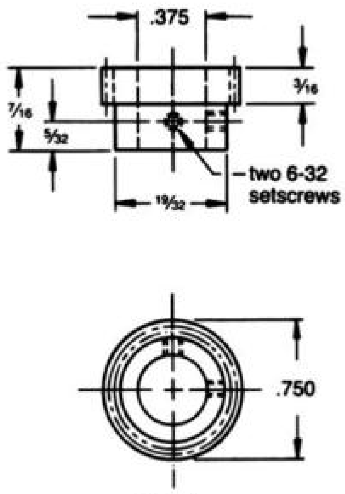
The cylinder bore should now be lapped. Machine the actual "business end" of the


tap for 8-32 setscrew
1¹⁵⁄₁₆
⁵⁄₁₆
¹³⁄₃₂
185
¼" bolt holes (2)
1
³⁄₁₆
light press fit into bearing block
ream .3755"
¾
¹⁄₁₆
¹⁵⁄₁₆
BRONZE BUSHING
³⁄₃₂" oil hole
ream ¼"
1.031
²¹⁄₃₂
ream ½"
.500
1.375
2
3⁵⁄₃₂
¹³⁄₁₆
¾
¼
¼
¼" bolt holes (2)
counterbore ¹³⁄₁₆" dia. × ³⁄₁₆" deep
INNER BEARING BLOCK
CRS
1 required
⁵⁄₁₆
1¹⁄₁₆
⁷⁄₃₂
Caution! This dimension for threaded holes only.
1½
ream ½"
tap 10-32
2
tap 8-32
To fit: '61 to '72 Chrysler breaker points.
OUTER BEARING BLOCK
CRS
1 required
³⁄₃₂" oil hole
1.375
²⁵⁄₃₂
⅝
⅝
ream .3755"
light press fit into bearing block
BRONZE BUSHING

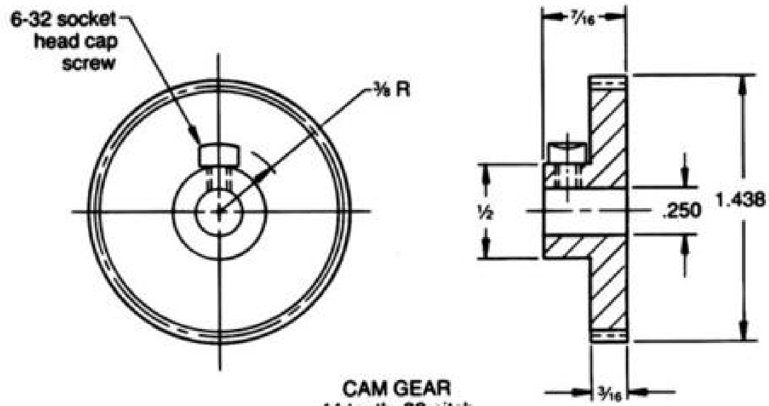

9

steel rod lapping tool about .002" smaller than the diameter of the cylinder bore; its length is about 2-1/8". The distance from this section to the lathe chuck is roughly 3/4" and should be undercut for clearance. Use *fine* valve grinding compound, smearing a thin amount on the tool and inside the cylinder, too. Now, with the lapping tool in the lathe, try to push and twist the cylinder onto the tool. If it begins to bind, remove the cylinder and reduce the tool diameter by .001".

Now slide the cylinder all the way onto the arbor and hold onto the work. Using a fairly slow spindle speed, start the lathe. Slowly slide the work back and forth about 3/8" on the revolving arbor. After about a minute, stop the lathe, remove the cylinder, and add a little



GEAR
32 pitch, 22 teeth
CRS
1 required

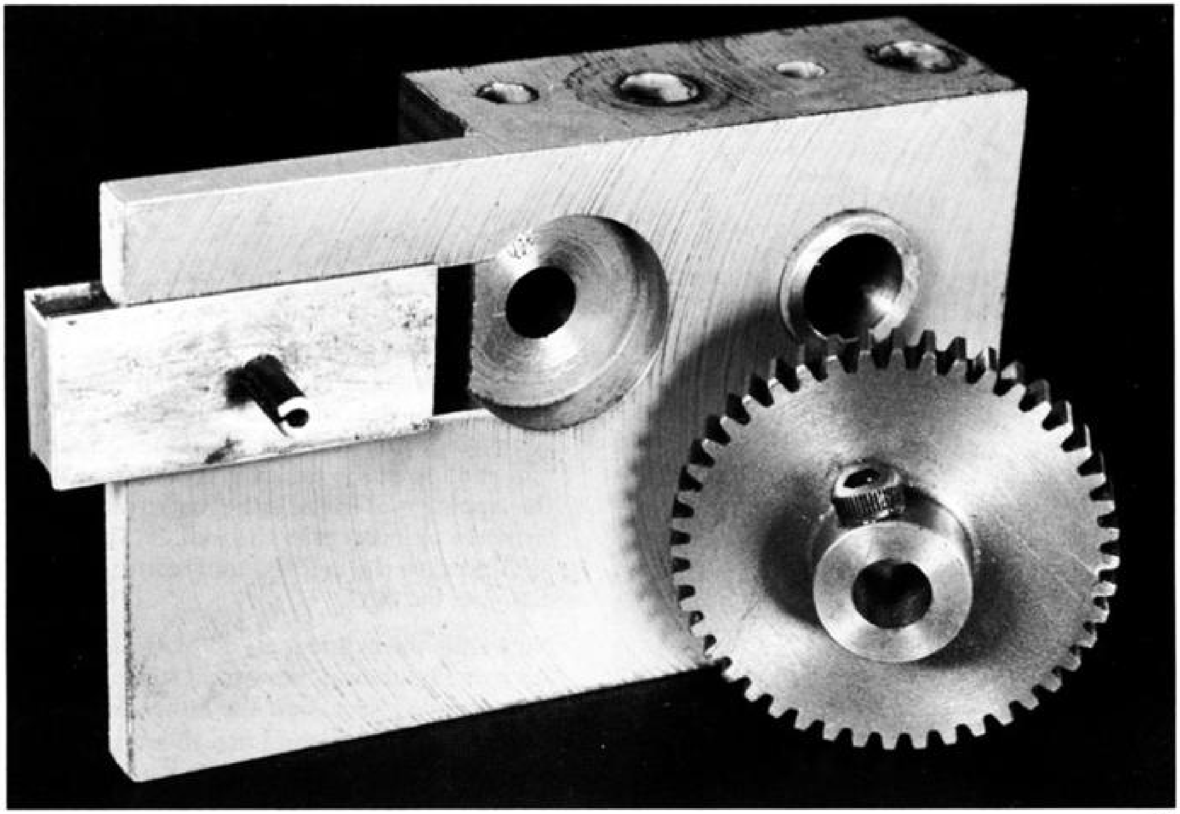


CAM GEAR
44 teeth, 32 pitch
brass or steel
1 required

more grinding compound; repeat the process. When finished, all portions of the cylinder will have a uniform gray appearance. It's important that *all* the grit in the cylinder be removed; scrub it out with a toothbrush and distillate.

Photo 10 shows the support for the Inner Crankshaft Bearing, the Large Gear, and the Valve Push "Rod"; the latter item, obviously, is not a rod at all, but a rather substantial grooved piece of metal that slides in a cutout in its supporting frame. The hex socket cap screw visible on the gear hub is actually the "cam lobe" that activates the valve push rod. That's right! You might call it a "bolt head cam"! Now if you're beginning to think I have bolts in my head, read on!

The socket head screw was firmly threaded into the gear hub, then mounted on a lathe mandrel and the bolt head slowly machined down to a certain height over the gear hub diameter – that is, the distance necessary to properly activate the valve rod. Finally, a file



10

was used to round off the sharp edges on each side of the bolt head. Presto! – the world's easiest-to-make cam! Well, are those horribly obvious gaps in each side of the "bolt head cam" still bothering you? Then take another look at the valve push "rod." It confronts the cam with such a large flat surface that irregularities in the cam itself are smoothly passed over.

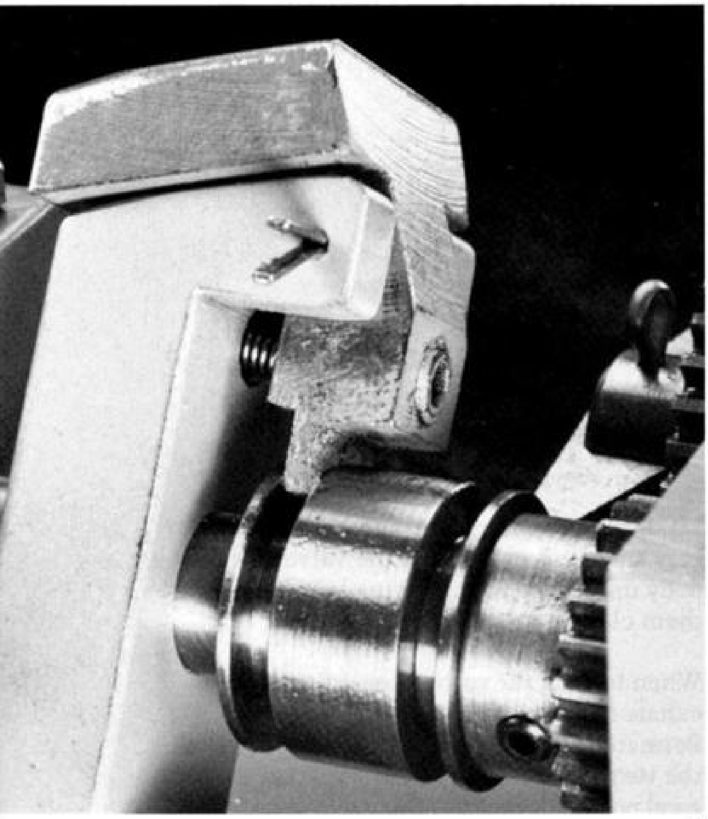
I machined my own cast iron Timing Gears; they're very close to standard size, but if you prefer to buy readymade gears, they are available (the large one is brass and the small one is steel) from Stock Drive Products, 2101 Jericho Turnpike, New Hyde Park, NY 11040. The stock number for the large gear is 1B2-N32044 and the small is 1C2-N32022. You'll have to enlarge the bore in the small gear to 3/8".

Note that in Photo 11 the Governor Weight mechanism is controlled by a compression spring recessed into the holding arm. The hex socket screw controls the RPM at which the governor is activated.

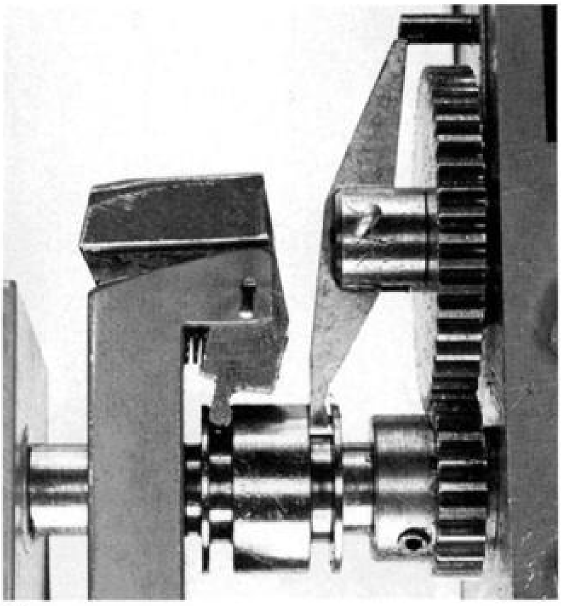
Photo 12 is a view from above looking down on the governor. When the engine is either at rest or the RPMs are too low, the governor locking mechanism will be in this position. Observe that the dowel "catch pin" affixed to the cam push "rod" (near the perimeter of the large gear) is in the "open" position in relation to the tapered locking arm, thus allowing the motor to fire.

Look at Photo 13. When the RPMs become excessive, centrifugal force on the governor weight activates the sliding spool on the crankshaft, pulling the locking arm to this position. The exhaust valve is now held in an open position until the motor slows to a lower RPM.

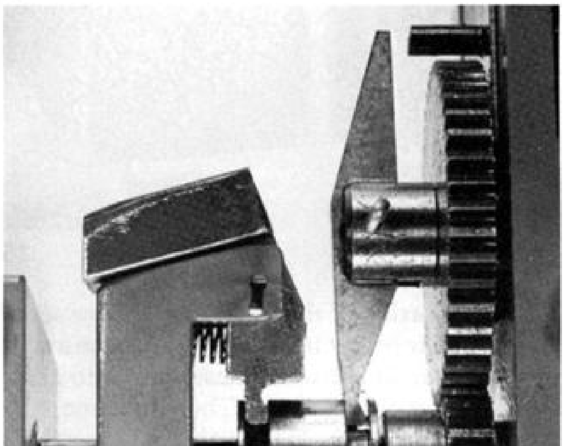
When machining the Intake Valve Body (Photo 14) and the Exhaust Valve Body, always start with the valve seat section. First, carefully center drill, then slowly and gently drill a 7/64" hole through the block. Follow with a No. 31 drill; then ream to 1/8". Now



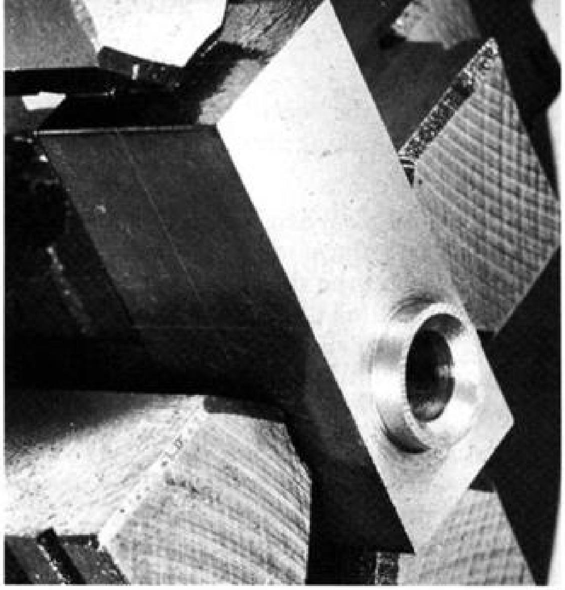
11



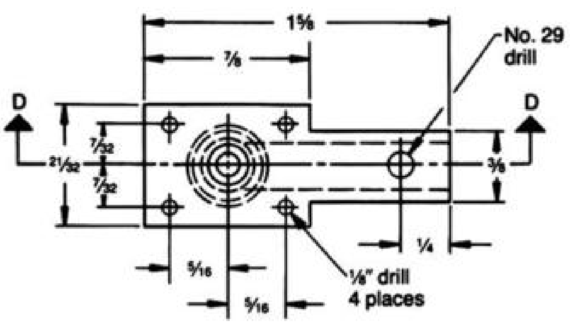
12

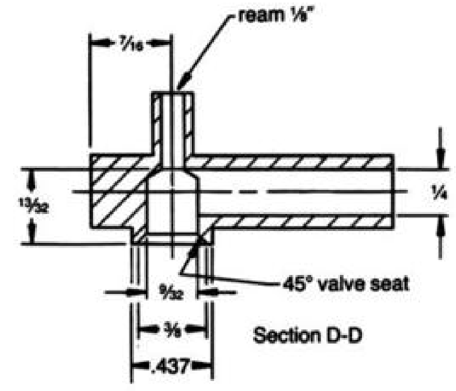


13

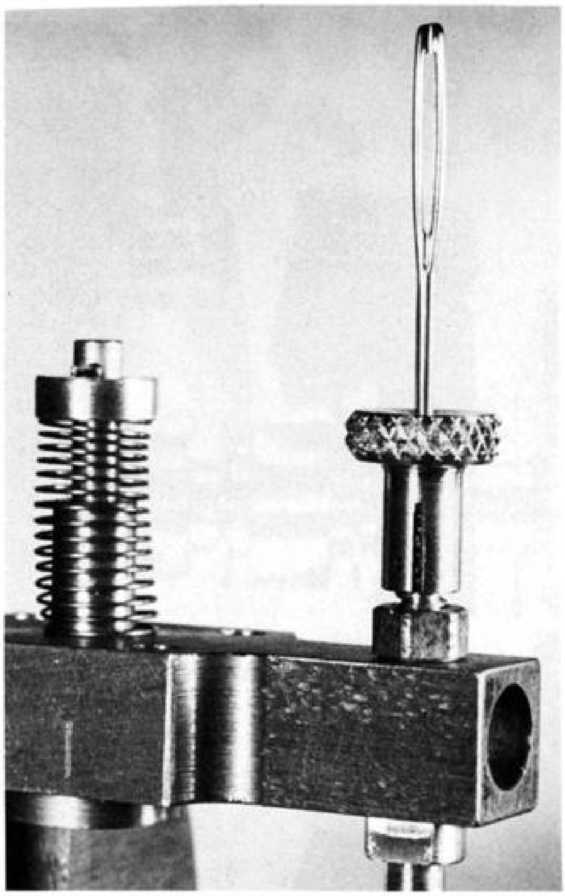


14

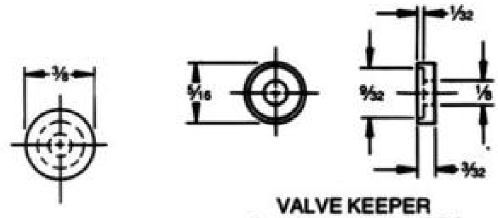

1⅝
⅞
No. 29 drill
D
D
21/32
7/32
7/32
⅜
¼
5/16
5/16
⅛" drill 4 places


ream ⅛"
7/16
13/32
¼
9/32
45° valve seat
⅜
.437

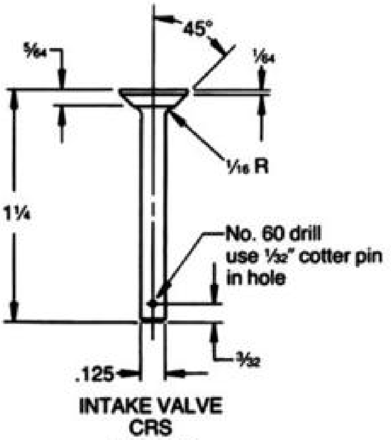
Section D-D



15


⅜
5/16
1/32
9/32
⅛
3/32

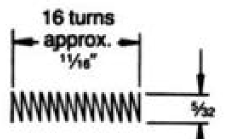
VALVE KEEPER
aluminum brass, or CRS
1 required


45°
5/64
1/64
1/16 R
1¼
No. 60 drill use 1/32" cotter pin in hole
3/32
.125

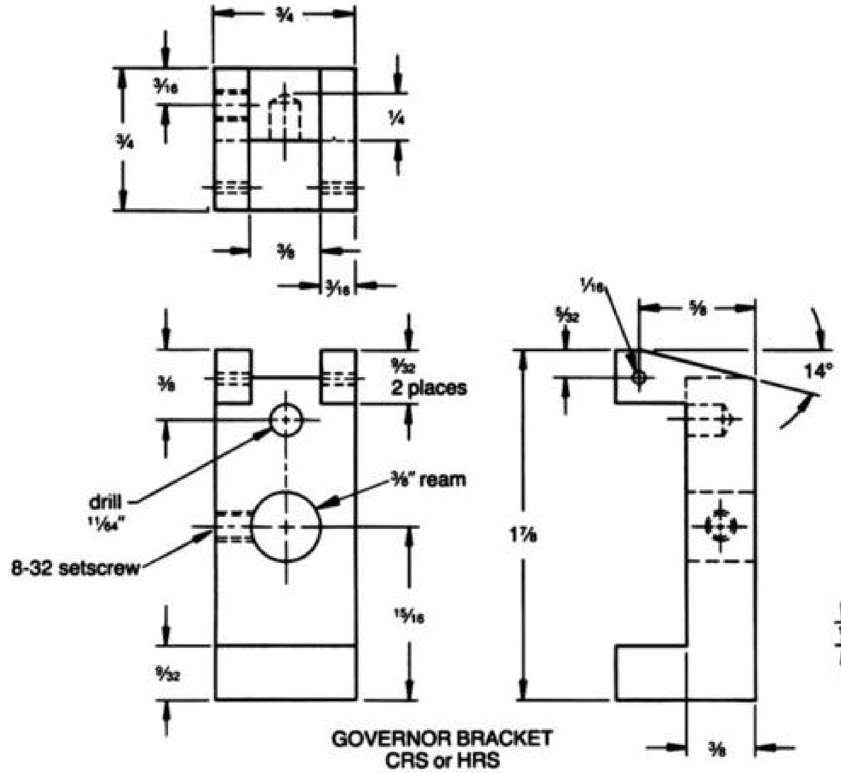
INTAKE VALVE
CRS
1 required

enlarge a portion of the hole for the valve seat and chamber below it. The second operation on either the intake or exhaust body is to drill the intake or exhaust hole. Then machine down the block to form the valve guide section. Upon completion of the two units and the valves, it's necessary to lap in the valve seats. A fine grit valve grinding compound is best – the finer the better. I use a 600 grit carborundum powder left over from a telescope grinding kit. Lapping should continue until a uniform gray surface is evident on the valve seat in the body units. Use a magnifying lens to examine them closely.

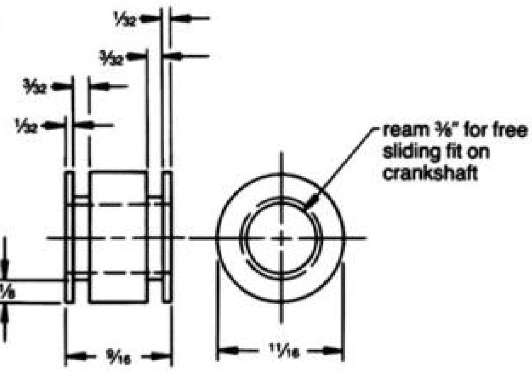
When bolting the carburetor unit to the exhaust unit, apply a very small amount of Permatex silicone *Form-A-Gasket* between the two surfaces. Be careful – we don't want goop oozing down into the valve seats! Of


16 turns approx.
1 1/16"
5/32

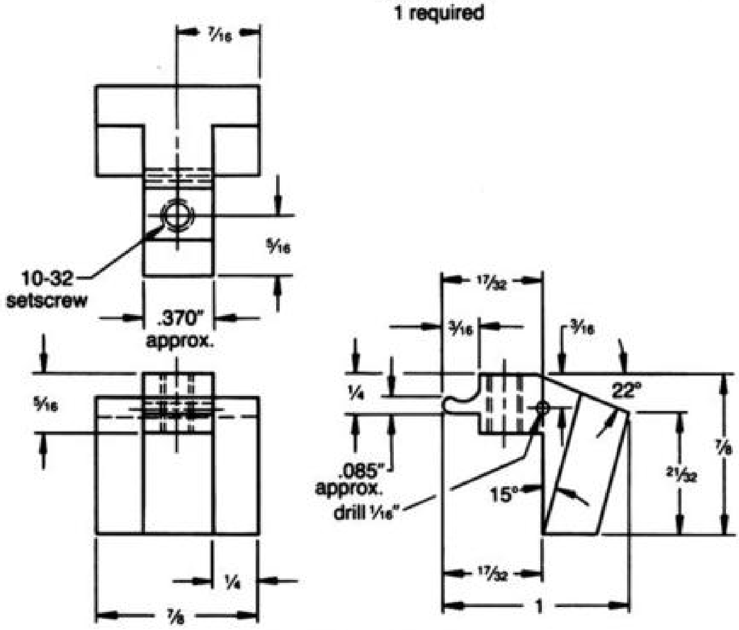
GOVERNOR COMPRESSION SPRING
.020" dia. wire (approx.)
1 required


¾
3/16
¼
¾
⅜
3/16
9/32 2 places
⅜
drill 11/64"
⅜" ream
8-32 setscrew
1 5/16
9/32
1/16
5/32
⅝
14°
1⅞
⅜

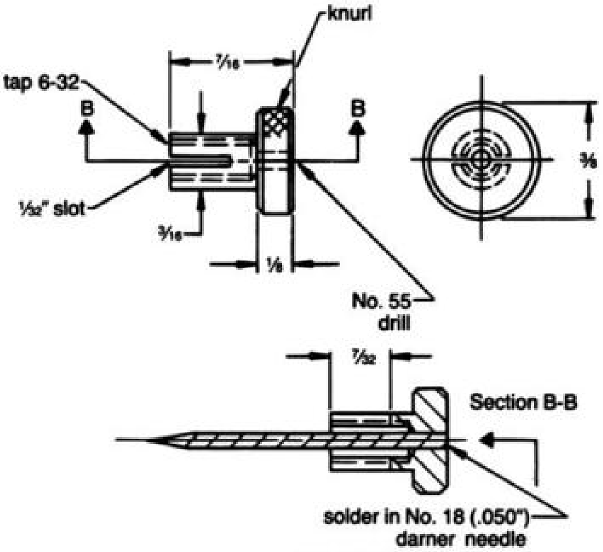
GOVERNOR BRACKET
CRS or HRS
1 required


1/32
3/32
3/32
1/32
ream ⅜" for free sliding fit on crankshaft
⅛
9/16
1 1/16

GOVERNOR SPOOL
CRS
1 required


7/16
10-32 setscrew
5/16
.370" approx.
5/16
17/32
3/16
3/16
¼
22°
.085" approx.
drill 1/16"
15°
21/32
⅞
¼
17/32
1
⅞

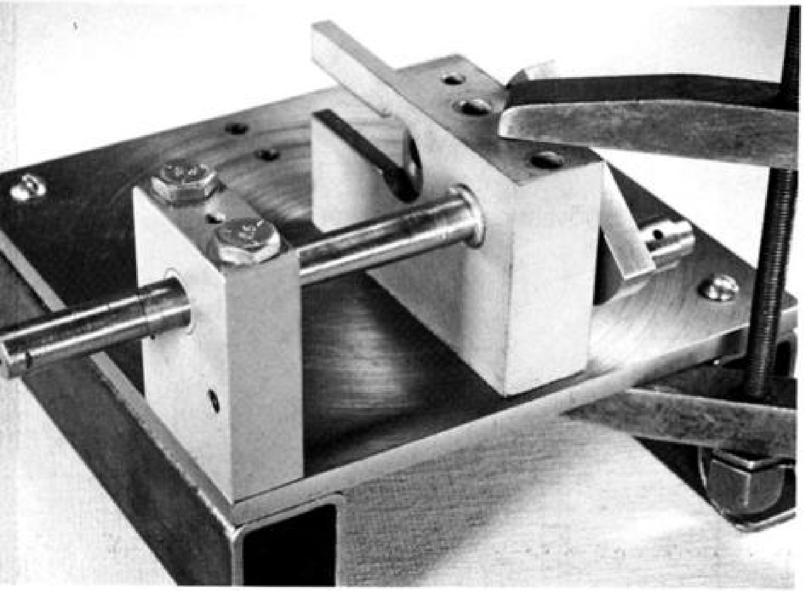
GOVERNOR WEIGHT
CRS
1 required


knurl
7/16
tap 6-32
B
B
1/32" slot
3/16
⅛
⅜
No. 55 drill
7/32
Section B-B
solder in No. 18 (.050") darner needle

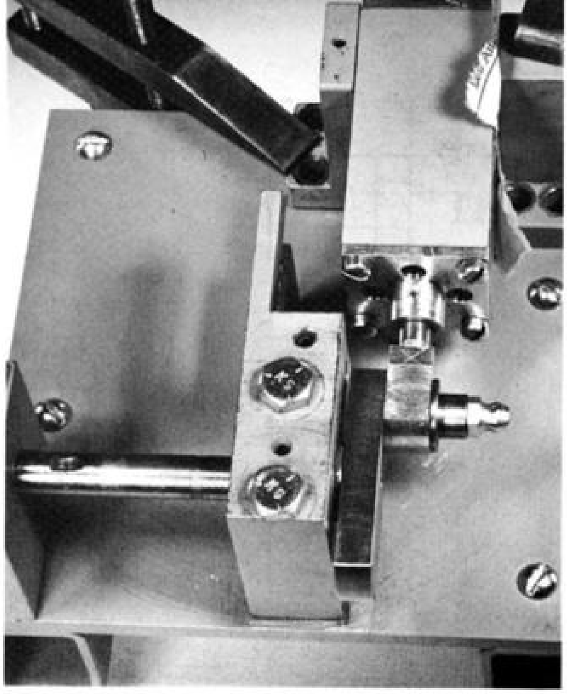
NEEDLE VALVE
brass or steel
1 required

course, some of the Permatex is also applied between the porthole pillar and the exhaust valve unit.

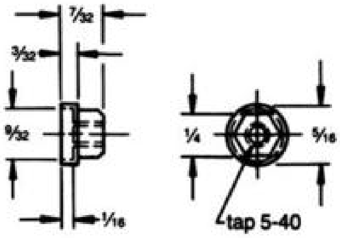
Photo 15 illustrates one method of positioning the darner needle preparatory to soldering it to the needle valve body. First screw the little knurled needle valve unit down as far as it will go. Then screw it back up about 1/32". Push the darner needle downward until it stops against the seat in the carburetor jet. Now apply a small piece of solder on top of the knurled knob and against the needle shaft. Flux and heat with a small torch until the solder flows smoothly around the needle. Finally, grind off the surplus portion of the needle. The slit in the knurled needle valve unit should be pinched together slightly for a snug fit on the threads. Don't let the simplicity of the carburetor-exhaust unit fool you; if you



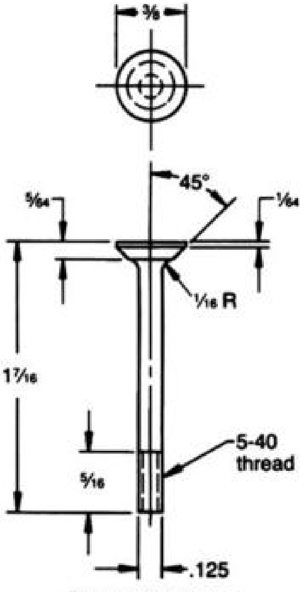
16



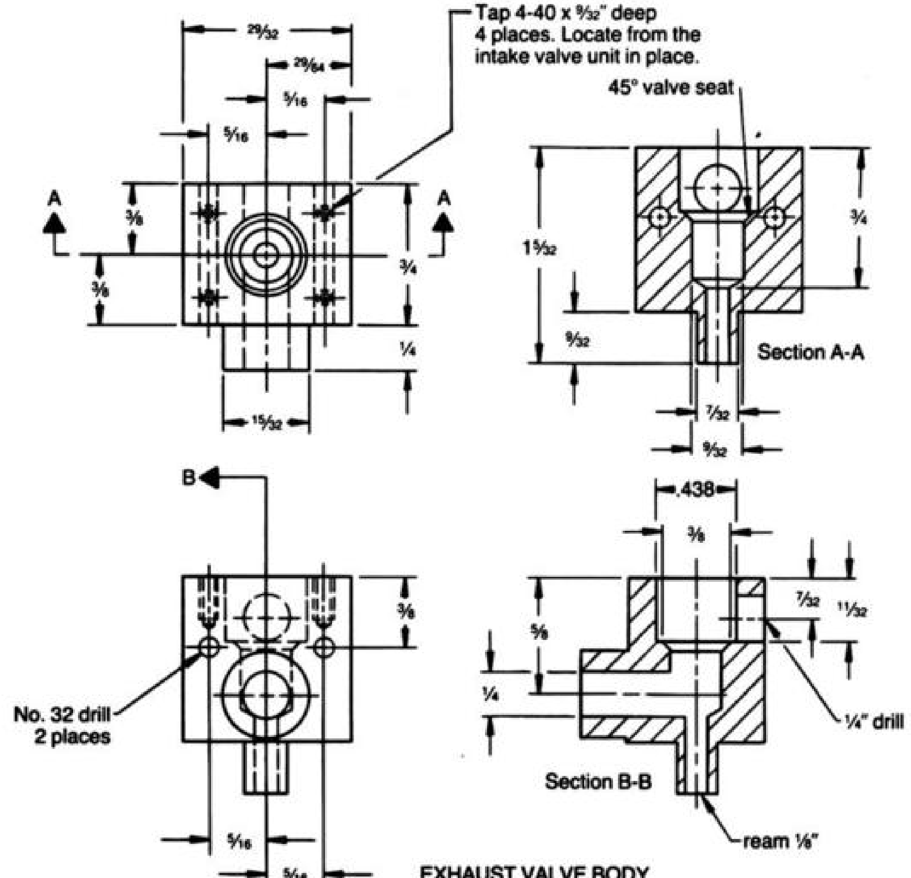
17


7/32
3/32
9/32
1/16
1/4
5/16
tap 5-40

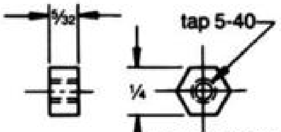
EXHAUST VALVE SPRING RETAINER
aluminum
1 required


3/8
45°
5/64
1/64
1/16 R
1 7/16
5-40 thread
5/16
.125

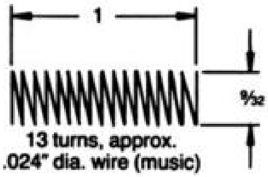
EXHAUST VALVE
CRS
1 required


Tap 4-40 x 9/32" deep 4 places. Locate from the intake valve unit in place.
29/32
29/64
5/16
5/16
A
A
3/8
3/8
3/4
1/4
15/32
45° valve seat
1 5/32
3/4
9/32
Section A-A
7/32
9/32
B
B
.438
3/8
3/8
5/8
7/32
11/32
1/4
No. 32 drill 2 places
1/4" drill
Section B-B
ream 1/8"
5/16
5/16

EXHAUST VALVE BODY
cast iron or steel
1 required

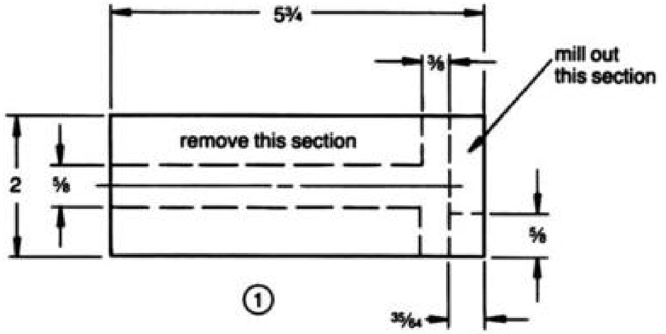

5/32
tap 5-40
1/4

VALVE STEM
LOCK NUT
CRS
1 required

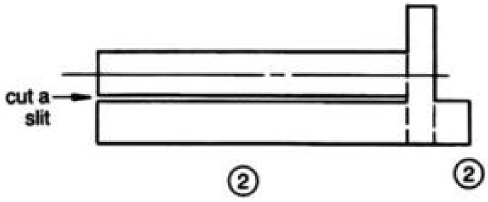

1
9/32
13 turns, approx.
.024" dia. wire (music)

EXHAUST VALVE SPRING
music wire
1 required

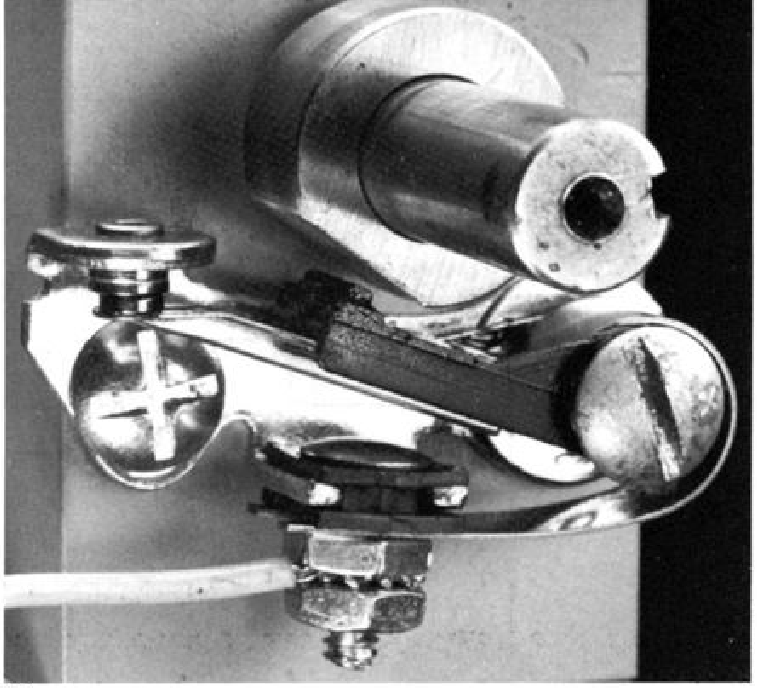
SEQUENCE FOR ROUGHING OUT CRANKSHAFT:



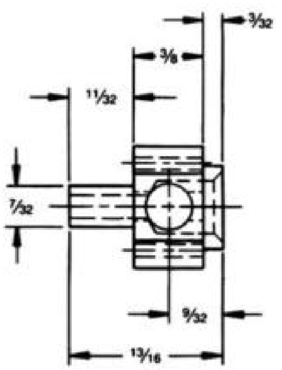
① Lay out rough guide lines on the blank.



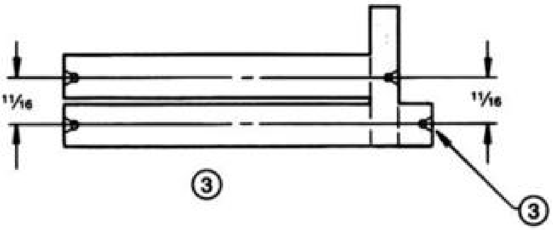
② Slit as indicated.



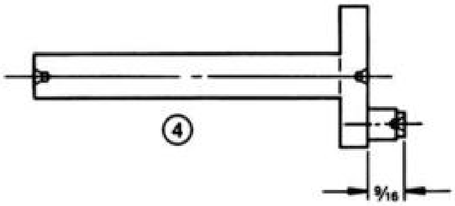
18



INTAKE VALVE BODY
CRS
1 required



③ Carefully lay out and drill 2 pairs of center holes. Then machine the crank journal to finish size.



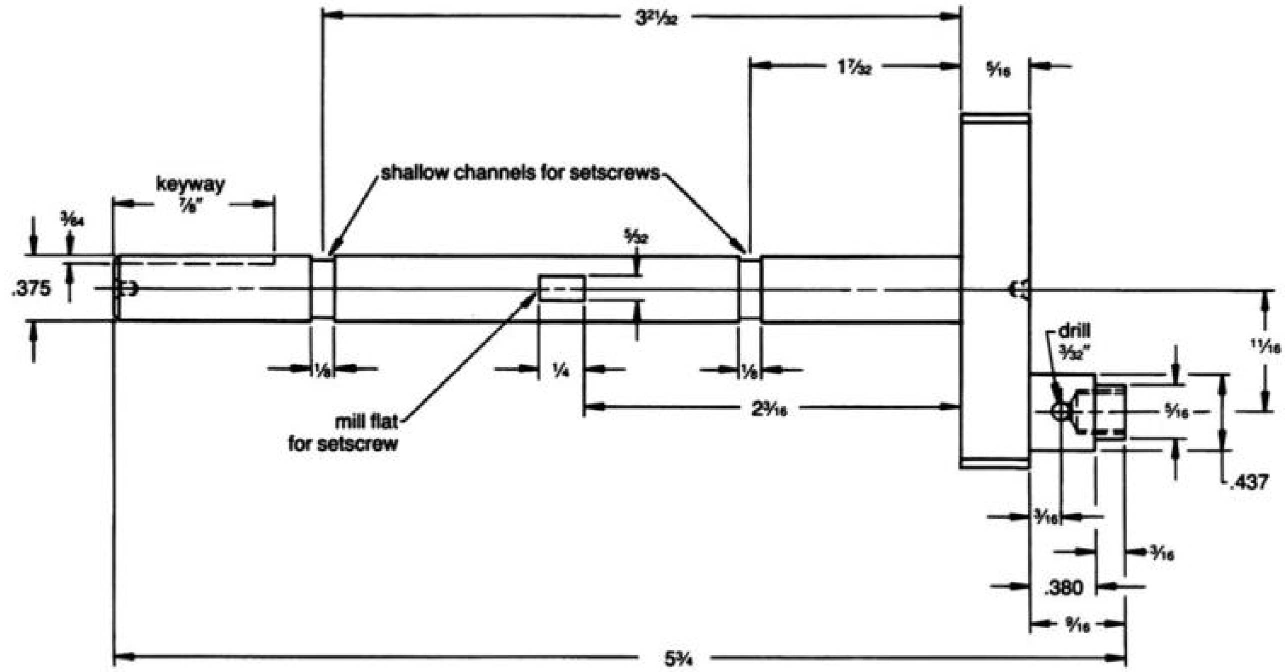
④ Cut off the remaining excess portion on the blank and proceed to machine the main shaft.

do careless work here, your motor will operate poorly – or worse, not at all!

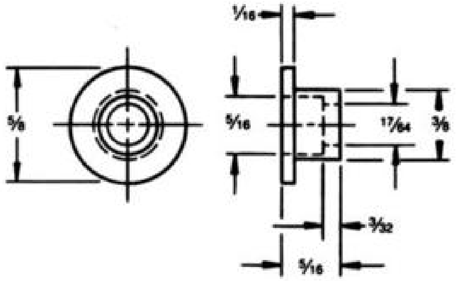
To secure the bearing blocks to the motor baseplate (Photo 16), begin by bolting the outer block true and square to the edge of the base. Then position the inner bearing in the correct location; insert the crankshaft to line up the two blocks. Clamp down the inner block and spot drill the two bolt holes. After threading the bolt holes in the base, again position the inner bearing block with the crankshaft inserted through both bearings. Bolt down the inner block. Now attempt to turn the crankshaft. Pretty tight? Don't be alarmed – despite very careful machining, I discovered that it was necessary to shim up one of the blocks by .001" to eliminate the binding. So, with a little shimming underneath one edge or the other, you should be able to free up the crankshaft.

The procedure for locating the cylinder and its two supporting pillars is shown in Photo 17. Note the double layer of newspaper inserted between the cylinder and the thrust pillar to act as a temporary shim. When everything is bolted down securely, it's essential that the side face of the cylinder block is kept in *light* contact with the mating surface on the porthole pillar – hence the adjusting setscrew and steel thrust ball in the opposite pillar.

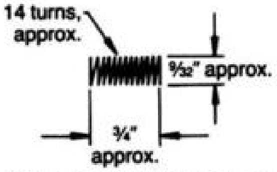
An easily obtainable '61 to '72 Chrysler breaker point set is employed for the ignition (Photo 18). It is attached to the outer bearing block. A recessed setscrew in the "cam" sleeve on the crankshaft facilitates easy


3 21/32
1 7/32
5/16
keyway
7/8"
3/64
shallow channels for setscrews
5/32
.375
1/8
1/4
1/8
2 3/16
mill flat for setscrew
drill 3/32"
11/16
5/16
.437
3/16
3/16
.380
9/16
5 3/4

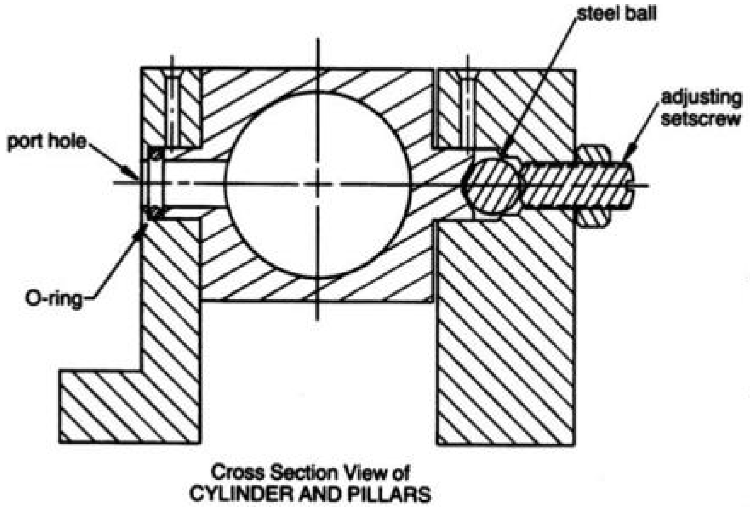
CRANKSHAFT
HRS or CRS
1 required


1/16
5/8
5/16
17/64
3/8
3/32
5/16

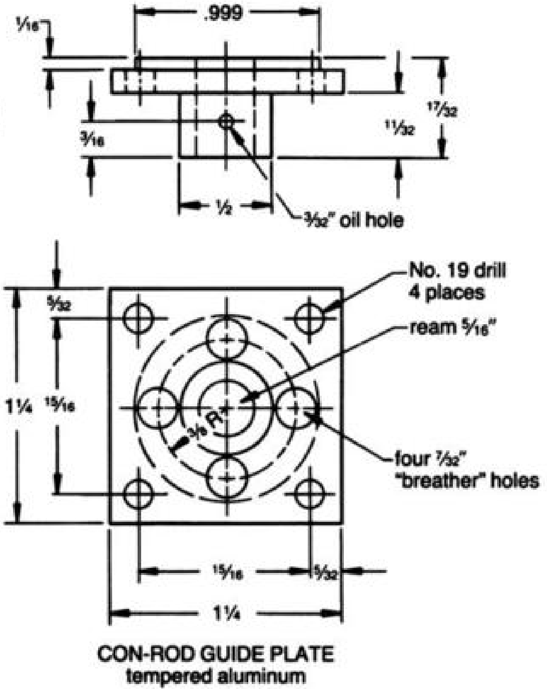
CRANKPIN RETAINING WASHER
CRS
1 required


14 turns, approx.
9/32" approx.
3/4" approx.

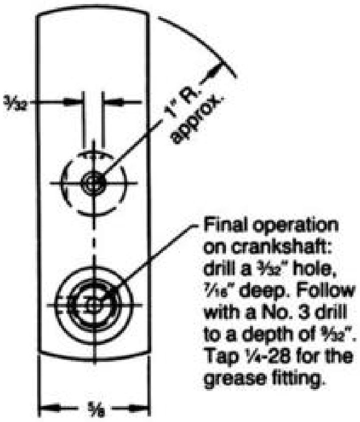
INTAKE VALVE SPRING
.015" dia. music wire
1 required

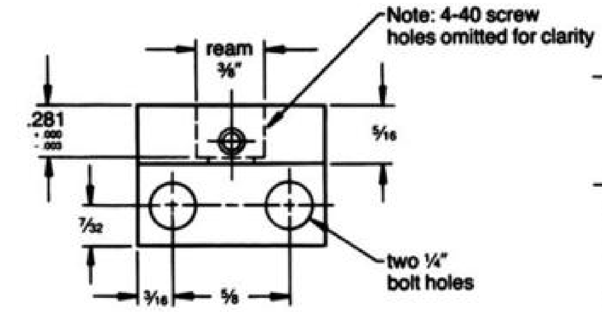

steel ball
adjusting setscrew
port hole
O-ring

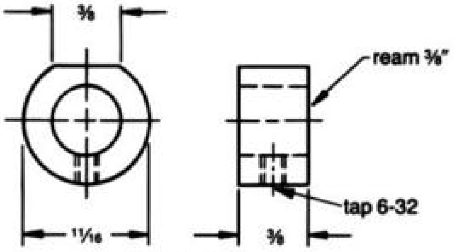
Cross Section View of
CYLINDER AND PILLARS
at the pivot axis


1/16
.999
17/32
11/32
3/16
1/2
3/32" oil hole
No. 19 drill 4 places
ream 5/16"
5/32
1 1/4
15/16
3/8 R
four 7/32" "breather" holes
15/16
5/32
1 1/4

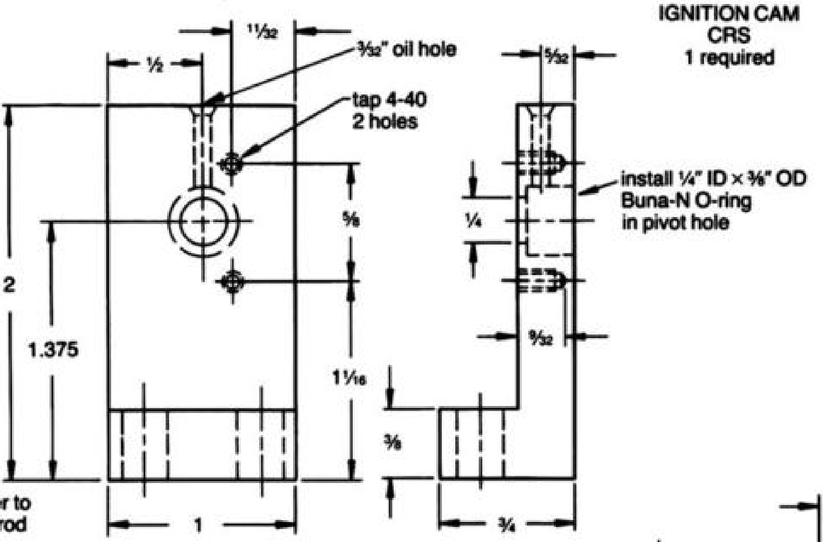
CON-ROD GUIDE PLATE
tempered aluminum
1 required


3/32
1" R. approx.
Final operation on crankshaft: drill a 3/32" hole, 7/16" deep. Follow with a No. 3 drill to a depth of 9/32". Tap 1/4-28 for the grease fitting.
5/8

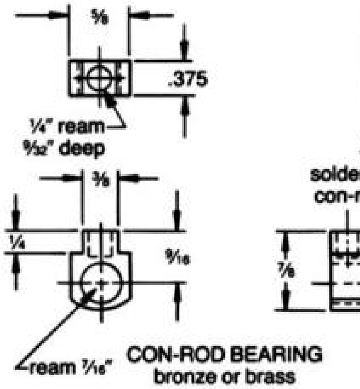

Note: 4-40 screw holes omitted for clarity
ream 3/8"
.281 +.000 -.003
5/16
7/32
two 1/4" bolt holes
3/16
5/8


3/8
ream 3/8"
tap 6-32
11/16
3/8

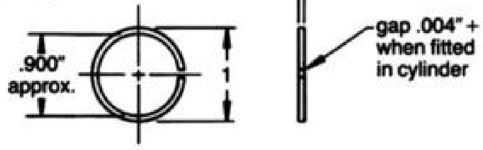
IGNITION CAM
CRS
1 required


11/32
1/2
3/32" oil hole
tap 4-40
2 holes
5/32
install 1/4" ID × 3/8" OD
Buna-N O-ring
in pivot hole
1/4
5/8
2
1.375
9/32
1 1/16
3/8
1
3/4

PORT HOLE PILLAR
CRS OR HRS
1 required


5/8
.375
1/4" ream 9/32" deep
3/8
1/4
9/16
solder to con-rod
7/8
ream 7/16"

CON-ROD BEARING
bronze or brass
1 required


1/16
gap .004" + when fitted in cylinder
.900" approx.
1

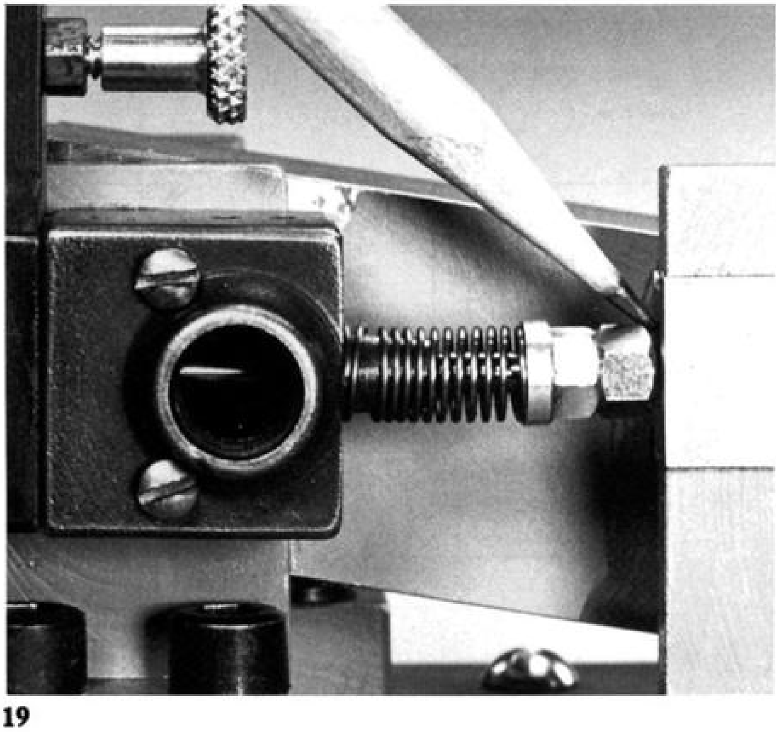
PISTON RING
cast iron
2 required

adjustment of spark timing. The flywheel has been removed for this view.

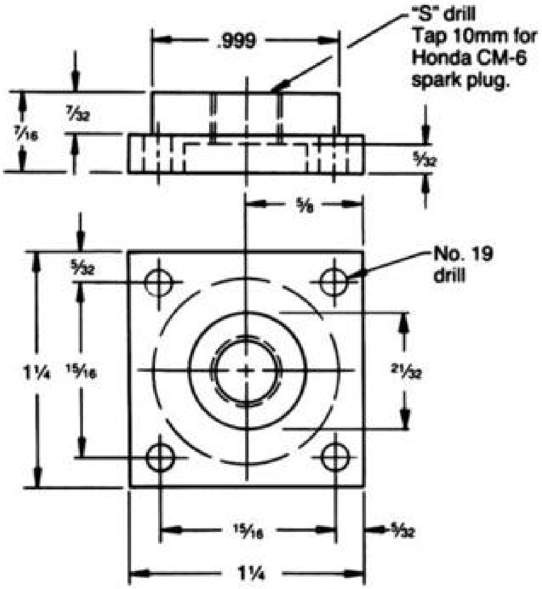
On the final assembly (Photo 19), adjust the valve stem locking nuts to leave a gap of about 1/32" between the push "rod" and the nut.

To time the exhaust valve, rotate the crankshaft (from the flywheel side of the engine) in a clockwise direction so the piston is about 5/32" from the end of its *outward* stroke. Disengage the cam gear from the shaft gear and rotate it to a position where the cam lobe just begins to open the exhaust valve. Now engage the gear with its mate.

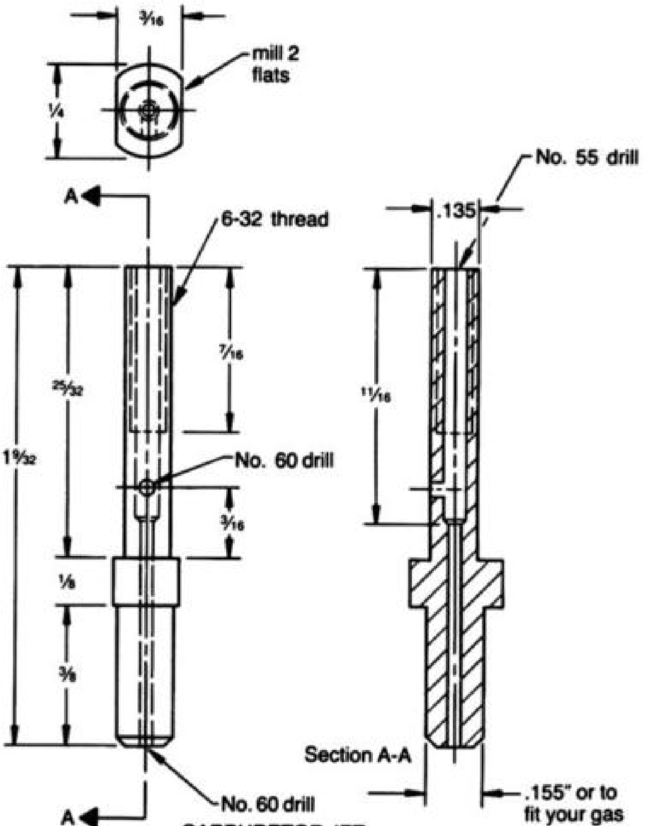
To time the spark, loosen the setscrew on the ignition cam. Rotate the crankshaft for the compression stroke and allow the piston to reach top dead center. Adjust the ignition cam so the spark will occur when the piston has *passed* top dead by about 5°. This type ignition will spark once every revolution but is effective only every other revolution.



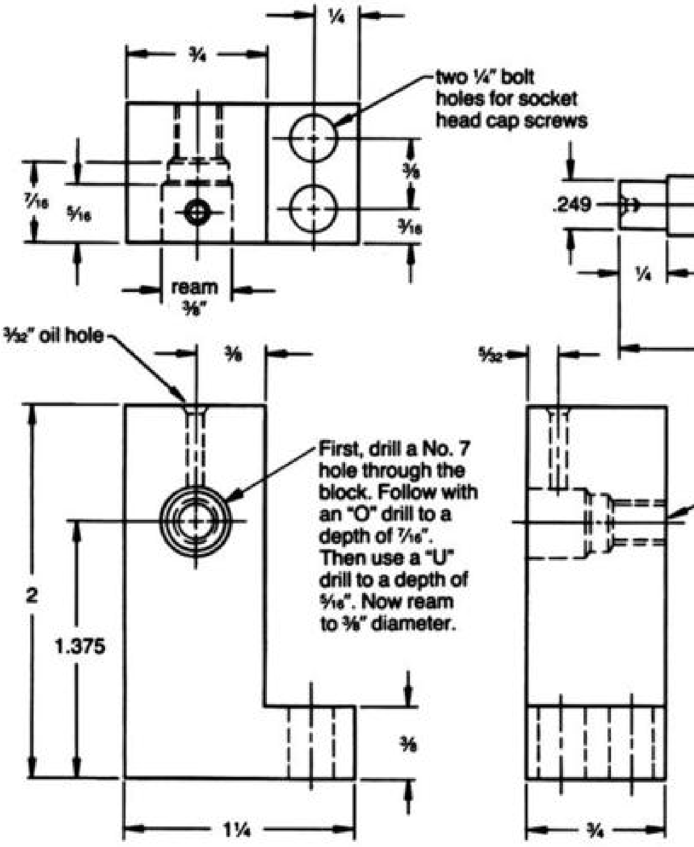
19


.999
"S" drill
Tap 10mm for
Honda CM-6
spark plug.
7/32
7/16
5/32
5/8
5/32
No. 19
drill
1¼
15/16
21/32
15/16
5/32
1¼

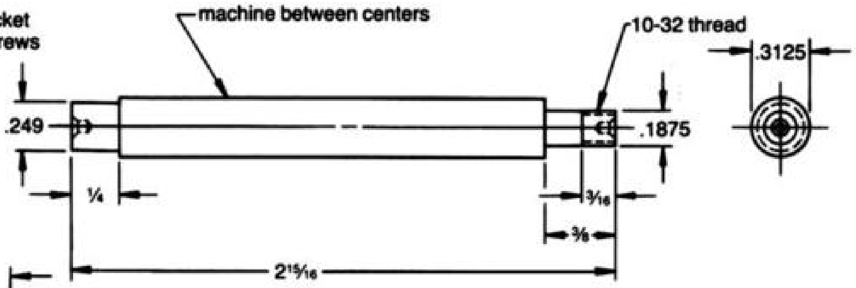
CYLINDER HEAD
tempered aluminum
1 required


3/16
mill 2
flats
¼
A
6-32 thread
No. 55 drill
.135
1 9/32
25/32
7/16
11/16
No. 60 drill
3/16
⅛
⅜
Section A-A
No. 60 drill
A
.155" or to
fit your gas
line tubing

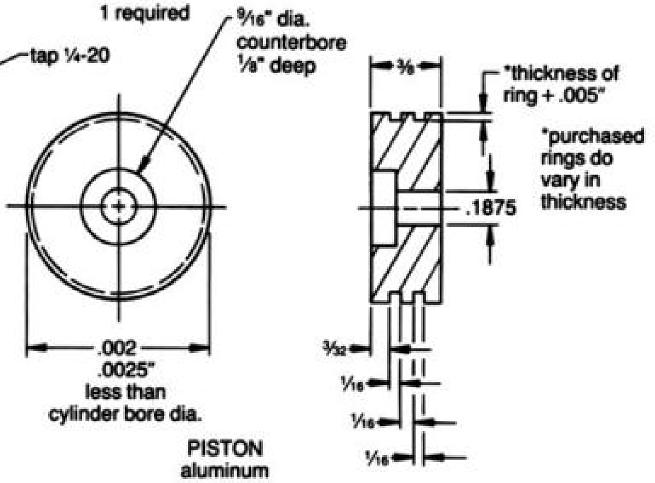
CARBURETOR JET
brass or CRS
1 required


¼
¾
two ¼" bolt
holes for socket
head cap screws
⅜
7/16
5/16
3/16
ream
⅜"
3/32" oil hole
⅜
5/32
First, drill a No. 7
hole through the
block. Follow with
an "O" drill to a
depth of 7/16".
Then use a "U"
drill to a depth of
5/16". Now ream
to ⅜" diameter.
tap ¼-20
2
1.375
⅜
1¼
¾

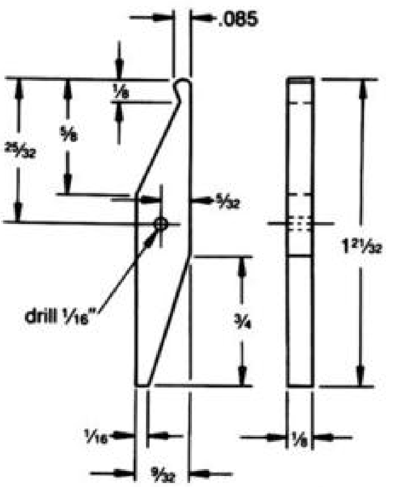
THRUST PILLAR
CRS or HRS
1 required


machine between centers
10-32 thread
.3125
.249
.1875
¼
3/16
⅜
2 15/16

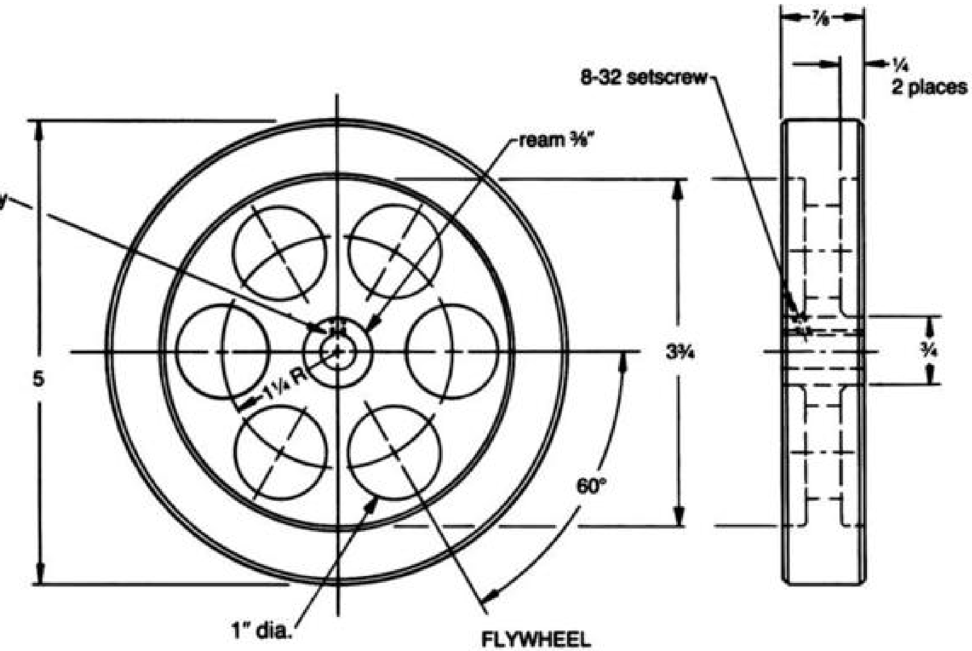
CON-ROD
CRS
1 required


9/16" dia.
counterbore
⅛" deep
⅜
*thickness of
ring + .005"
*purchased
rings do
vary in
thickness
.1875
.002
.0025"
less than
cylinder bore dia.
3/32
1/16
1/16
1/16

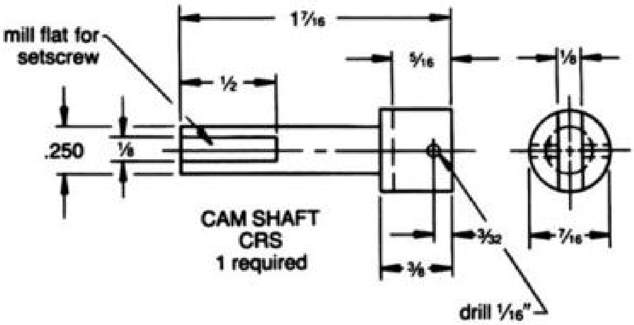
PISTON
aluminum
1 required


.085
1/8
5/8
25/32
5/32
drill 1/16"
1 21/32
3/4
1/16
1/8
9/32

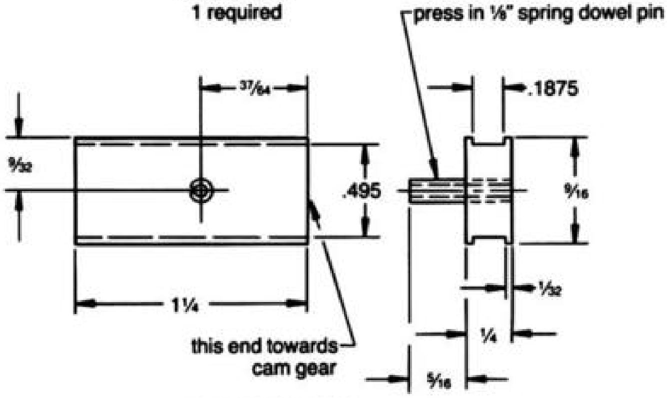
GOVERNOR PAWL
CRS
1 required


3/32" keyway
8-32 setscrew
ream 3/8"
7/8
1/4
2 places
5
3 3/4
3/4
1 1/4 R
60°
1" dia.

FLYWHEEL
HRS or CRS
1 required


mill flat for setscrew
1 7/16
1/2
5/16
1/8
.250
1/8
3/32
7/16
3/8
drill 1/16"

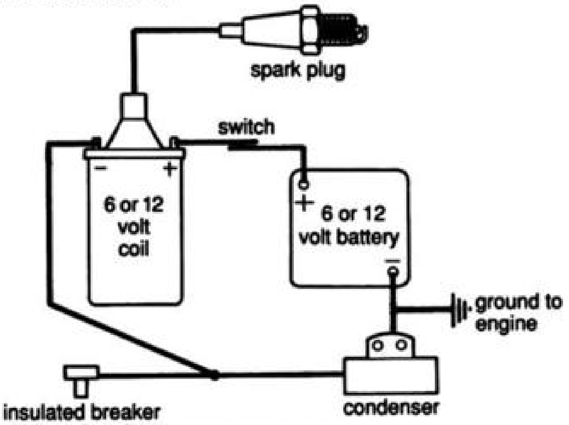
CAM SHAFT
CRS
1 required


press in 1/8" spring dowel pin
37/64
.1875
9/32
.495
9/16
1 1/4
1/32
1/4
5/16
this end towards cam gear

VALVE PUSH "ROD"
CRS
1 required

Visible in Photo 1 is an easily constructed "tuna can" gas tank. I soldered in a new lid cut from another piece of tin can, then added a brass filler pipe with a threaded and vented cap. A short piece of copper tubing was soldered into the side of the can near the base and connected to the engine with a piece of gas-proof plastic tubing. Lack of proper lubrication for the piston and cylinder of this little engine was solved merely by mixing two-cycle motor oil into regular gasoline at a ratio of 1 to 25. The gasoline level in the tank should be about 1/4" below the air intake pipe on the carburetor.

When the engine is running, its speed is regulated by the amount of spring tension on the governor weight; too much tension and the motor will only run fast and never "hit and miss." If the spring tension is too weak, the engine will "hit and miss" before reaching the proper speed and will die. If further adjustment of the governor is needed, it can be done by loosening the setscrew on the governor bracket and moving the whole unit a small amount one direction or the other on the crankshaft.


spark plug
switch
-
+
6 or 12 volt coil
+
6 or 12 volt battery
-
ground to engine
condenser
insulated breaker point on engine

IGNITION CIRCUIT

For the uninitiated, don't expect your engine to start on the first half dozen flips of the flywheel! There are four main reasons for it to just sit there "doin' nuttin'." Ignition, compression, and carburetion are the main culprits; to this add *excessive* friction. If your motor is too tight or the parts are misaligned, it'll never start. Some modelmakers prefer "running in" their engines on a drill press or lathe until everything turns freely – a very good idea!

The ignition spark should be able to jump a gap of a *least* 3/8". Compression is usually quite low at first on a new engine – it'll improve with use.

Adjusting the carburetor needle valve is always a problem on a new motor. On my engine, it's necessary to open up the needle valve about 2-1/4" turns from the closed position; this will give you only an approximate setting for your needle valve as each motor is slightly different.

When attempting to start your engine, place your finger momentarily over the intake pipe while giving the flywheel a vigorous turn. Keep your eye on the *intake* valve stem; as soon as it jumps inward, remove your finger from the intake. Continue with at least half a dozen vigorous turns of the flywheel on the compression stroke. If nothing happens, try choking again. If it runs a few revolutions and then dies, this could indicate a fuel mixture that's too rich or one that's too lean. So, by trial and error, adjust the needle valve in or out until the engine continues to run.

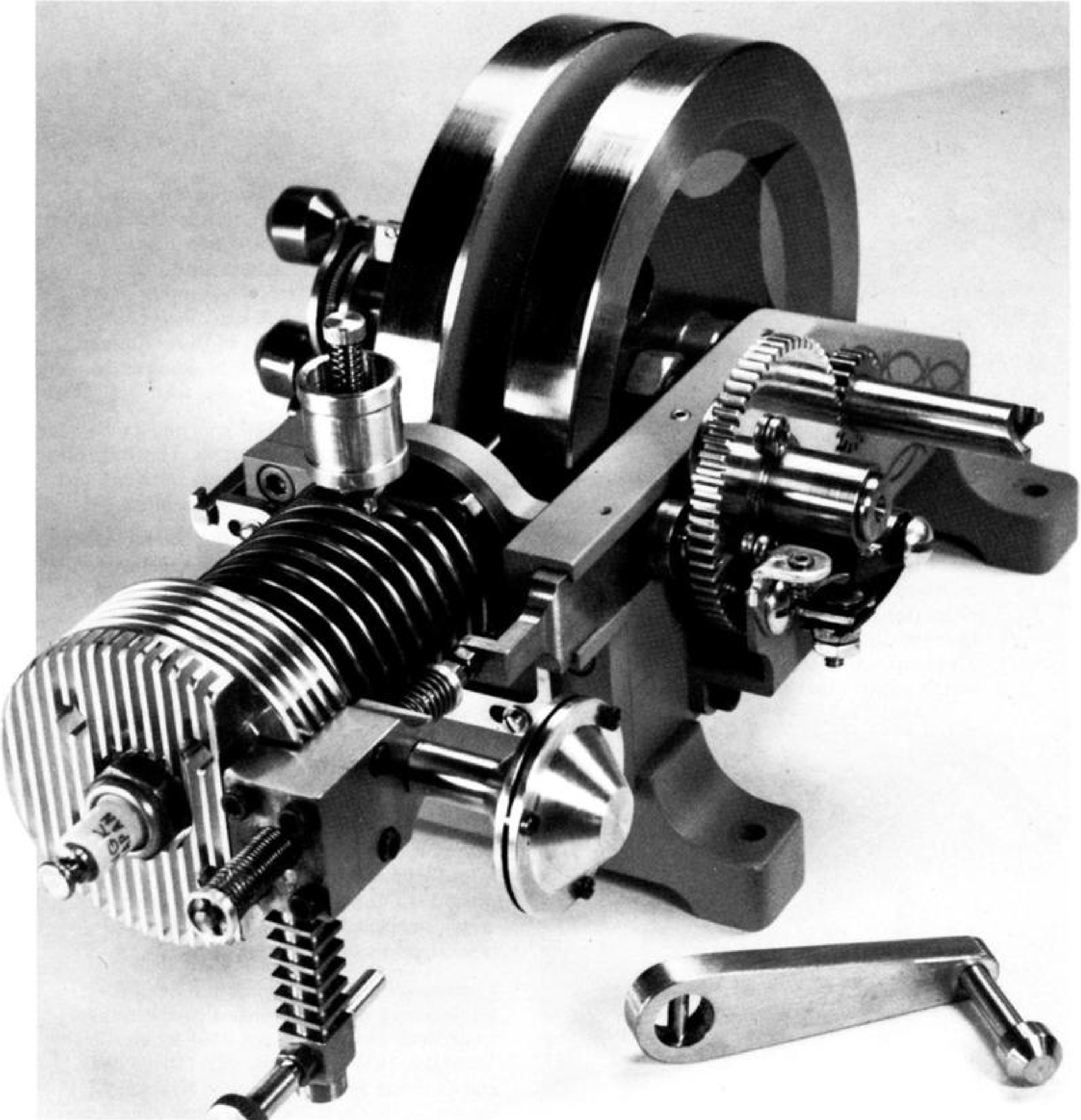
If you see gas vapor spurting outward from the intake pipe while the engine is running, it will indicate a leaky intake valve seat – regrind the valve! Also, if the intake valve spring is too weak, the valve won't close quickly enough, and if it's too strong, the motor won't receive enough air. Don't be afraid to experiment with different springs if you think there's a problem there.

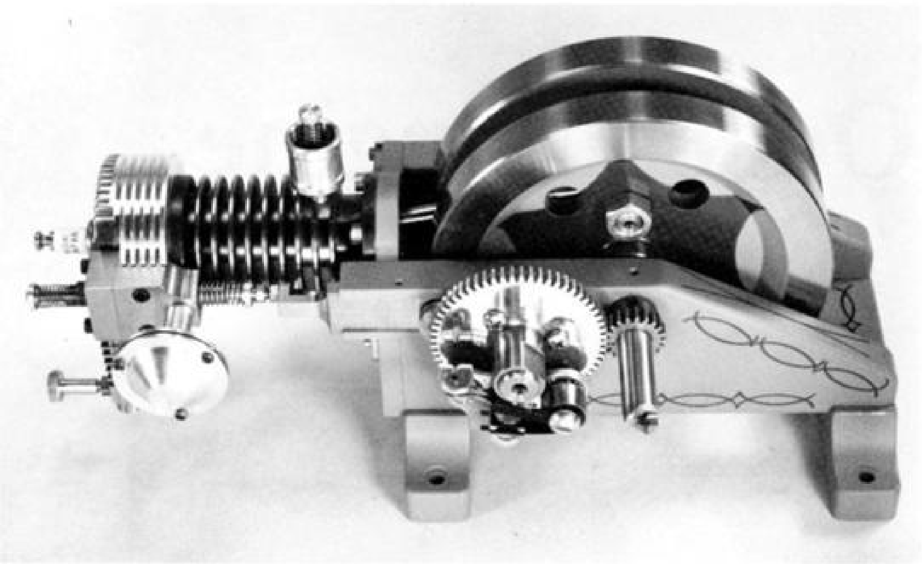
So there you have it, the essentials of my "bare bones" oscillating gas engine – a fascinating motor to watch in operation!

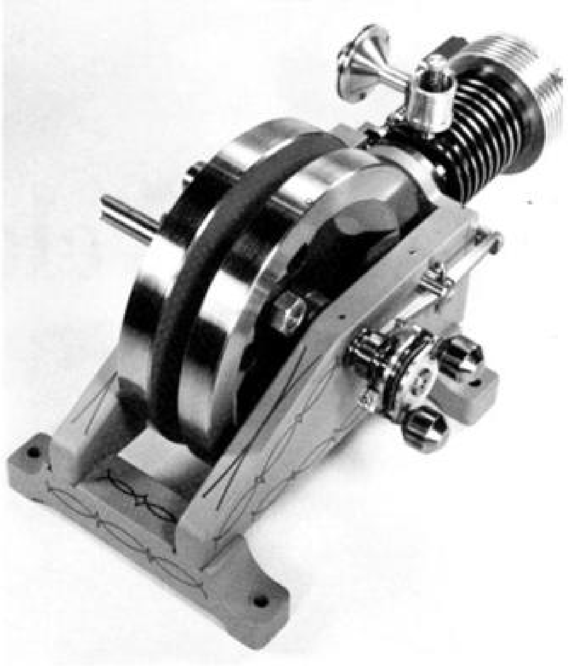
BILL OF MATERIALS

NO. REQ'D.	PART	FINISHED SIZES	NO. REQ'D.	PART	FINISHED SIZES
1	Baseplate	¼ x 5½ x 5½" HRS or CRS	1	Ignition Cam	⅜ x 11/16" round stock CRS
2	Base Legs	⅛ x 1 x 1½ x 6¾" HRS rectangular tubing	1	Spark Plug	10mm Honda (motorcycle) spark plug, CM-6
1	Outer Bearing Block	⅝ x 1½ x 2" CRS	1	Cylinder Head	7/16 x 1¼ x 1¼" aluminum
1	Crankshaft	⅝ x 2 x 5¾" HRS or CRS	1	Con-Rod Guide Plate	17/32 x 1¼ x 1¼" aluminum
1	Inner Bearing Block	13/16 x 2 x 3 5/32 CRS or HRS	1	Governor Bracket	¾ x ¾ x 1⅞" CRS
1	Bronze Bushing	½ x ⅝" bearing bronze	1	Governor Compression Spring	5/32 x 11/16", 16 turns .020" dia. music wire
1	Bronze Bushing	¾ x 15/16" bearing bronze	1	Governor Weight	⅞ x ⅞ x 1"CRS
1	Cylinder Block	1¼ x 1 11/16 x 2½ CRS or HRS	1	Governor Spool	9/16 x 11/16" round stock CRS
1	Flywheel	⅞ x 5" round disk HRS or CRS	1	Carburetor Jet	¼ x 1 9/32" round stock brass
1	Valve Push Rod	¼ x 9/16 x 1¼ CRS	1	Keyway Stock	3/32 x 3/32 x ⅞"
1	Governor Pawl	⅛ x 9/32 x 1 21/32" CRS	1	"O" Ring	¼" ID x ⅜" OD Buna-N "O" ring
1	Camshaft	½ x 1 7/16" CRS round stock	1	Breaker Point Set	'61 to '72 Chrysler breaker point set
1	Cam Gear	32 pitch, 44 teeth	1	Grease Fitting	
1	Gear	32 pitch, 22 teeth	4	Hex Bolts	¼-20 x 2 3/16"
1	Port Hole Pillar	¾ x 1 x 2" CRS	1	Setscrew	¼-20 x ⅝"
1	Thrust Pillar	¾ x 1¼ x 2" CRS	1	Hex Nut	¼-20
1	Steel Ball	5/16" dia.	4	Socket Head Cap Screws	8-32 x ½"
1	Exhaust Valve Body	29/32 x 1 x 1 5/32" CRS	4	Filister Head Cap Screws	8-32 x ½"
1	Intake Valve Body	21/32 x 13/16 x 1⅝" CRS	1	Setscrew	6-32 x ⅛"
1	Exhaust Valve	⅜ x 1 7/16" round rod CRS	1	Round Head Cap Screw	10-32 x 11/16"
1	Intake Valve	⅜ x 1¼" round rod CRS	1	Round Head Cap Screw	8-32 x ¼"
1	Exhaust Valve Compression Spring	9/32 x 1" – 13 turns, .024" dia. music wire	2	Filister Head or Socket Head Screws	4-40 x ⅞"
1	Intake Valve Compression Spring	9/32 x ¾" – 14 turns, .015" dia. music wire	4	Socket Head Cap Screws	¼-20 x ⅝"
1	Exhaust Valve Spring Retainer	7/32 x 5/16" aluminum	4	Socket Head Cap Screws	4-40 x ½"
1	Valve Stem Lock Nut	5/32 x ¼" – 5-40 thread	1	Cotter Pin	1/16" x 1¼"
1	Needle Valve Knob	⅜ x 7/16" round brass	1	Cotter Pin	1/16 x ⅝"
1	Darner Needle	No. 18 (.050")	1	Cotter Pin	1/32 x ⅜"
1	Valve Keeper	3/32 x 5/16" round aluminum	4	Round Head Cap Screws	10-32 x ½"
1	Con-Rod	5/16 x 2 15/16" round CRS	1	Socket Head Cap Screw	6-32 x ⅛"
1	Piston	⅜ x 1" round tempered aluminum	1	Hex Nut	6-32
2	Piston Rings	1/16 x 1" cast iron	1	Setscrew	10-32 x 3/16"
1	Con-Rod Bearing	⅜ x ⅝ x ⅞" bearing bronze or brass	1	Hex Nut	10-32
			1	Setscrew	8-32 x ⅜"

Six-cycle Oddball Engine



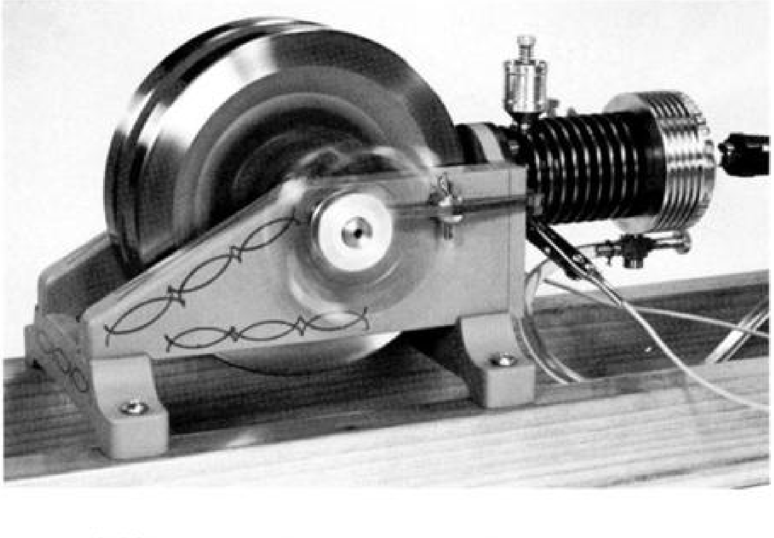




Tired of the same old run-of-the-mill model hit 'n miss engines? Well, here's one that should grab your attention; quaintly antique in design, its unusual features certainly qualify it to be termed an "oddball"!

A six-cycle motor is not new. That idea goes back to the late 1800s. So does the oddball crankshaft, which merely consists of a pin held by the two closely spaced flywheels. In those days, gas engines were a new development, and hundreds of inventors were busily designing their own version of a "perfect" motor.

In an ordinary four-cycle engine, a certain amount of burned gases remain in the cylinder every time it fires. In past times, the inventors reasoned that by extending the firing time to every third revolution, almost all of the burned gases would be dissipated from the cylinder. Then, upon firing, a more powerful explosion would occur. Their assumptions were correct.



Fuel-wise, the six-cycle is more efficient. However, that extra revolution between power strokes is also accompanied by a drop in sustained torque, which also results in less motor heat. It is this fact – less motor heat – that has allowed me to design an air cooled engine with no fan or blower, thus eliminating the troublesome problem of building and maintaining a water cooling system.

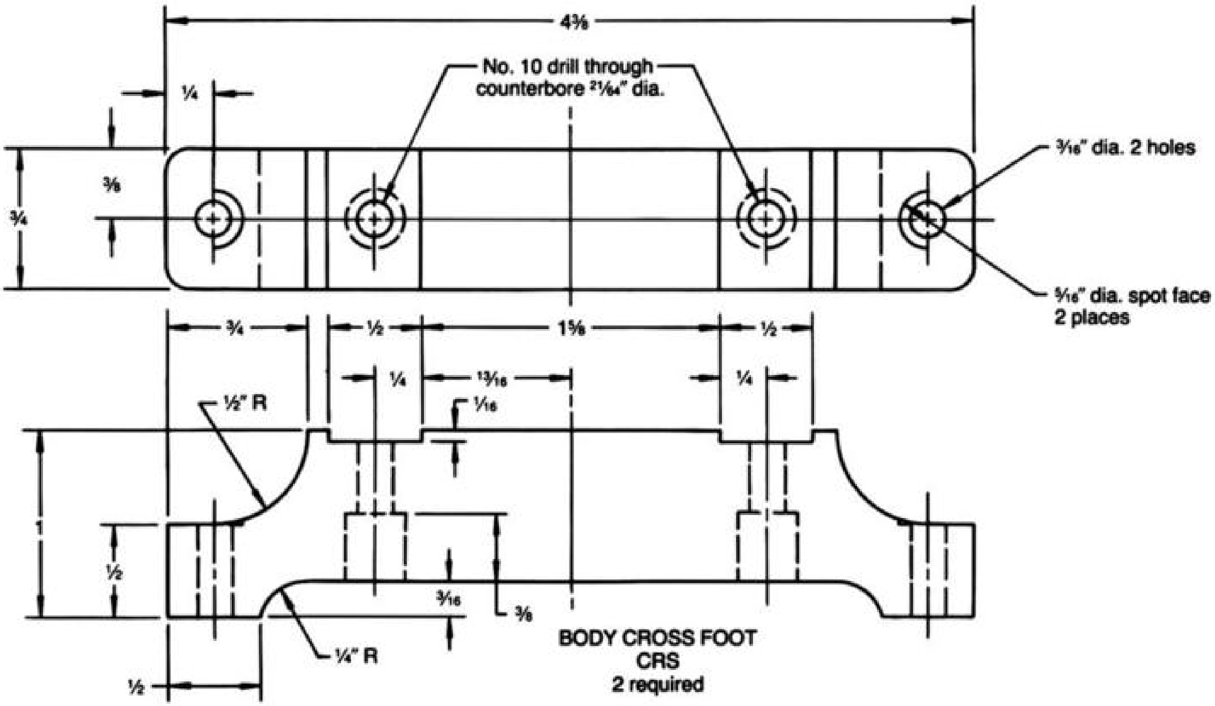
This little motor has a 3/4" bore and a rather long stroke by today's standards. There are no castings; it's constructed entirely from ordinary pieces of metal that require no welding.

My engine performs beautifully. Spring tension on the governor weights should be adjusted so the motor runs at about 700 rpm. At that speed, it emits a steady "putt, putt," firing about every 2/3 of a second, or approximately once every eight revolutions. I've had it running continuously at 700 rpm for an hour or more at a time, and even at 1000 rpm without a whimper. But don't forget that a six-cycle engine fires slowly and revolves swiftly; don't overdo the speed!

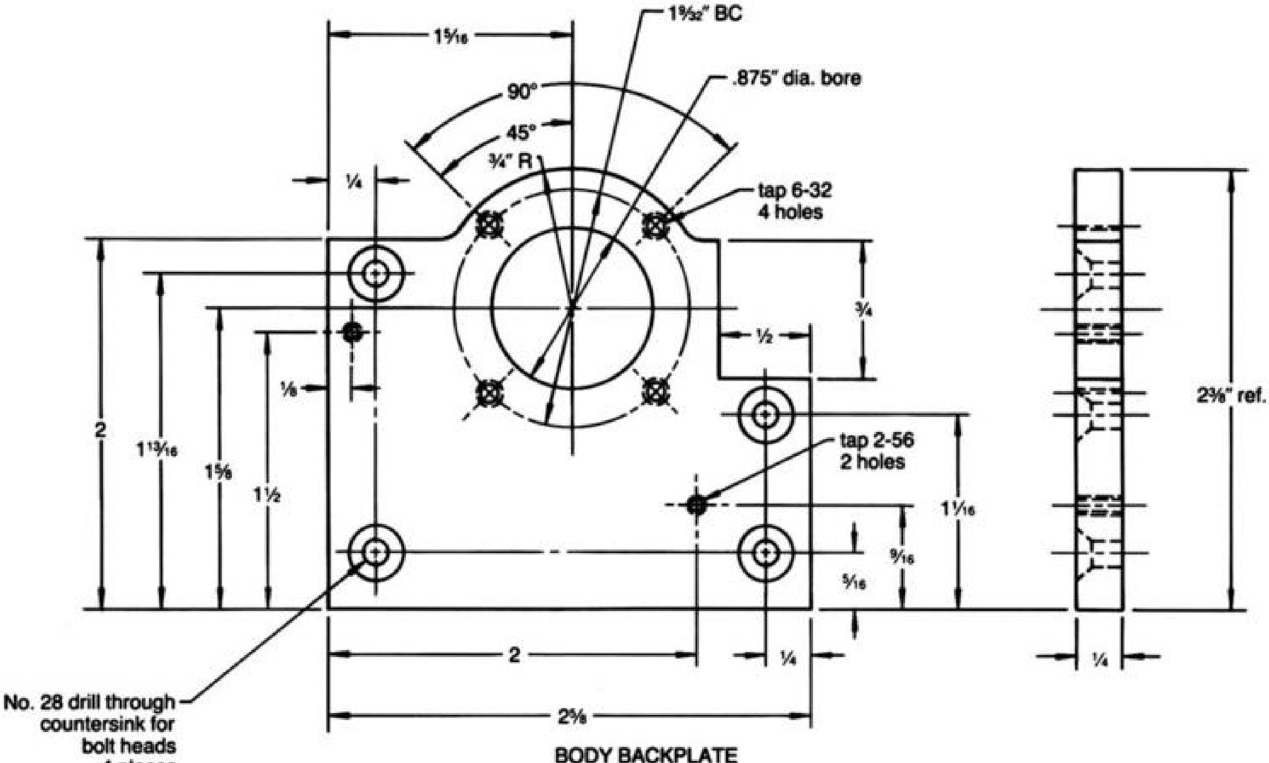
With precise craftsmanship as the "name of the game," you'll discover this to be an interesting and challenging project. Your reward is a most fascinating mechanism to watch in operation, with gears, arms, and wheels, all in vigorous motion!

I purchased the timing gears and the oil impregnated sintered bronze sleeve bearings from Stock Drive Products, 2101 Jericho Turnpike, New Hyde Park, NY 11040. The standard size gears will have to be altered somewhat, but no big problem here. The piston rings are available at Coles' Power Models, Box 788, Ventura, CA 93001, or Power Model Supply Company, Route 1, Box 177, DeSoto, MO 63020. Both companies stock cast iron rod for the cylinder and also miniature spark plugs. The Chrysler ignition breaker point set is readily available from auto supply stores.

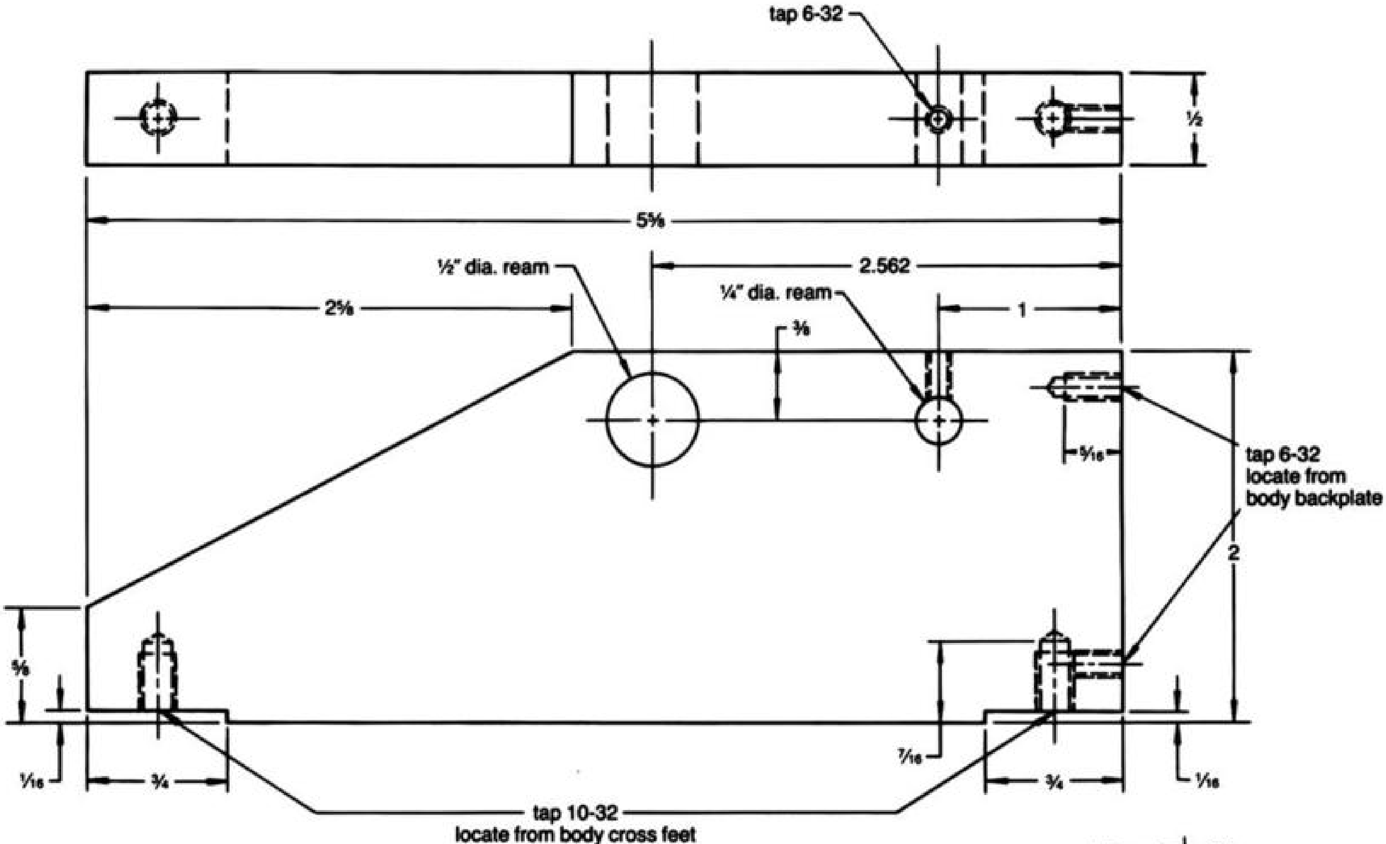
Many of the parts in this engine are machined in a vertical milling machine. I find it expedient to first machine any particular piece of metal perfectly square, one side to the other, and also the ends of the piece. The overall size of the blank is brought to the overall size of the part to be constructed. The blank is then


4⅜
No. 10 drill through
counterbore 21/64" dia.
¼
⅜
¾
3/16" dia. 2 holes
5/16" dia. spot face
2 places
¾
½
1⅝
½
¼
13/16
¼
½" R
1/16
1
½
3/16
⅜
¼" R
½

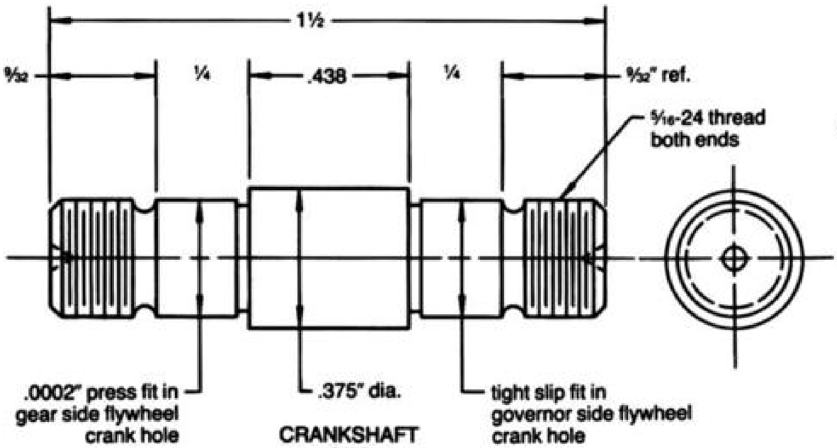
BODY CROSS FOOT
CRS
2 required


1 5/16
1 9/32" BC
.875" dia. bore
90°
45°
¾" R
¼
tap 6-32
4 holes
¾
½
⅛
2
1 13/16
1⅝
1½
tap 2-56
2 holes
1 1/16
9/16
5/16
2⅜" ref.
2
¼
2⅝
¼
No. 28 drill through
countersink for
bolt heads
4 places

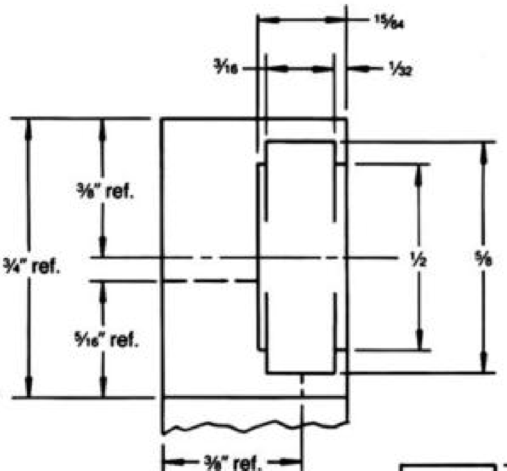
BODY BACKPLATE
CRS
1 required


tap 6-32
½
5⅝
½" dia. ream
2.562
¼" dia. ream
2⅜
1
⅜
5⁄16
tap 6-32
locate from
body backplate
2
⅝
7⁄16
1⁄16
¾
¾
1⁄16
tap 10-32
locate from body cross feet

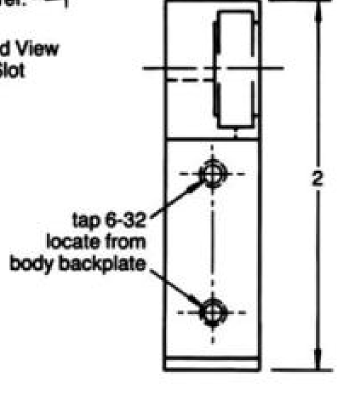
BODY UPRIGHT – GOVERNOR SIDE
CRS
1 required

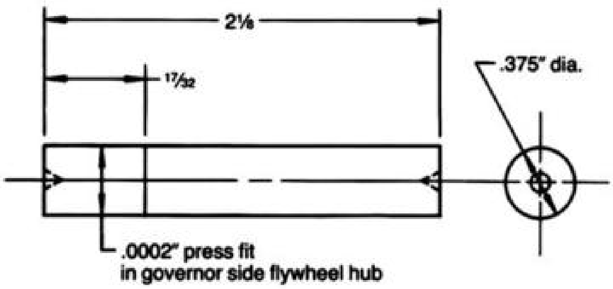

1½
9⁄32
¼
.438
¼
9⁄32" ref.
5⁄16-24 thread
both ends
.0002" press fit in
gear side flywheel
crank hole
.375" dia.
tight slip fit in
governor side flywheel
crank hole

CRANKSHAFT
CRS
1 required

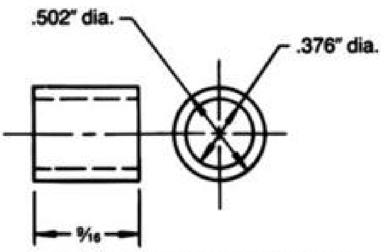

15⁄64
3⁄16
1⁄32
⅜" ref.
¾" ref.
5⁄16" ref.
½
⅝
⅜" ref.

Enlarged View
Of Slot

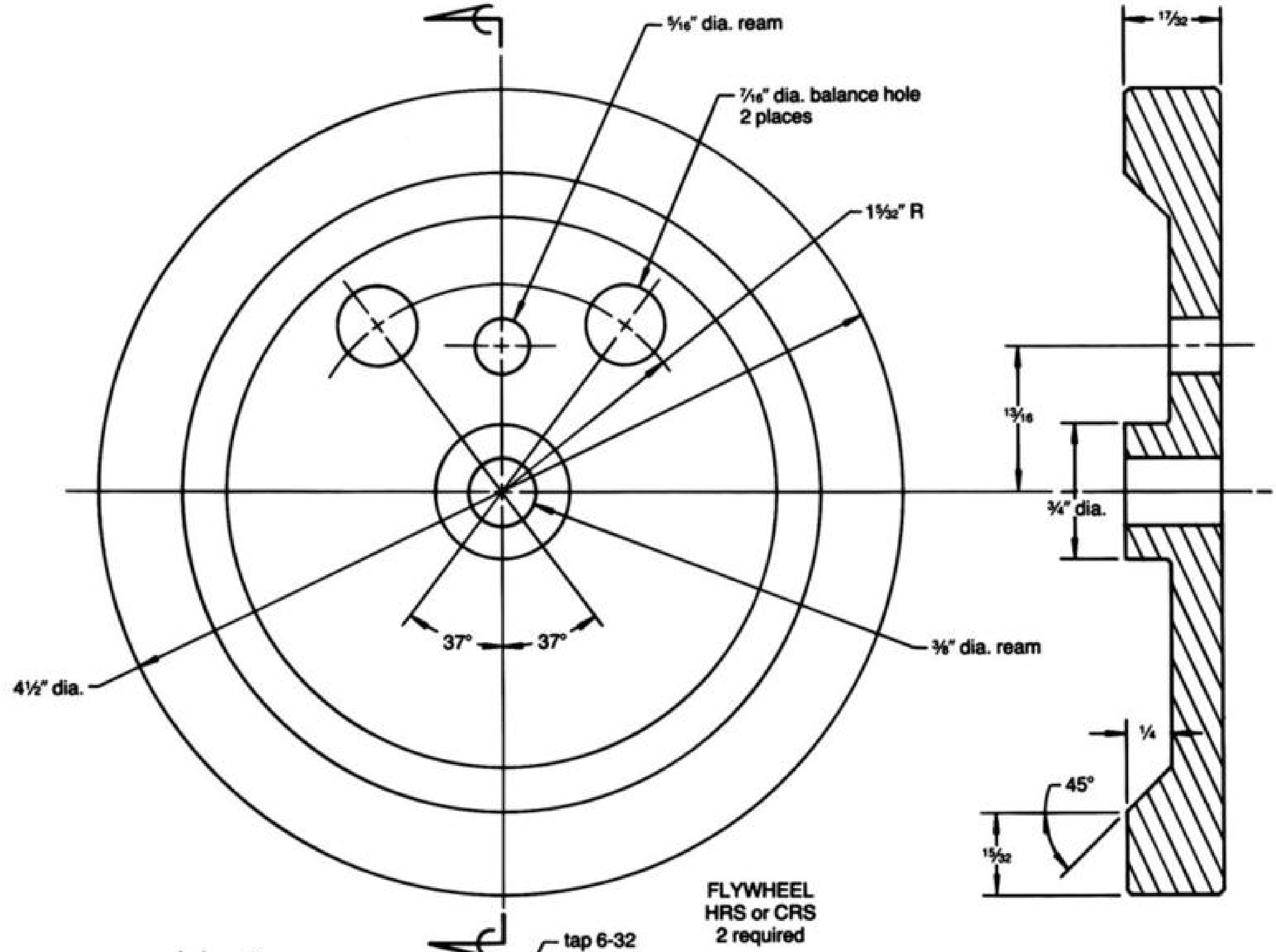

2
tap 6-32
locate from
body backplate


2⅛
17⁄32
.375" dia.
.0002" press fit
in governor side flywheel hub

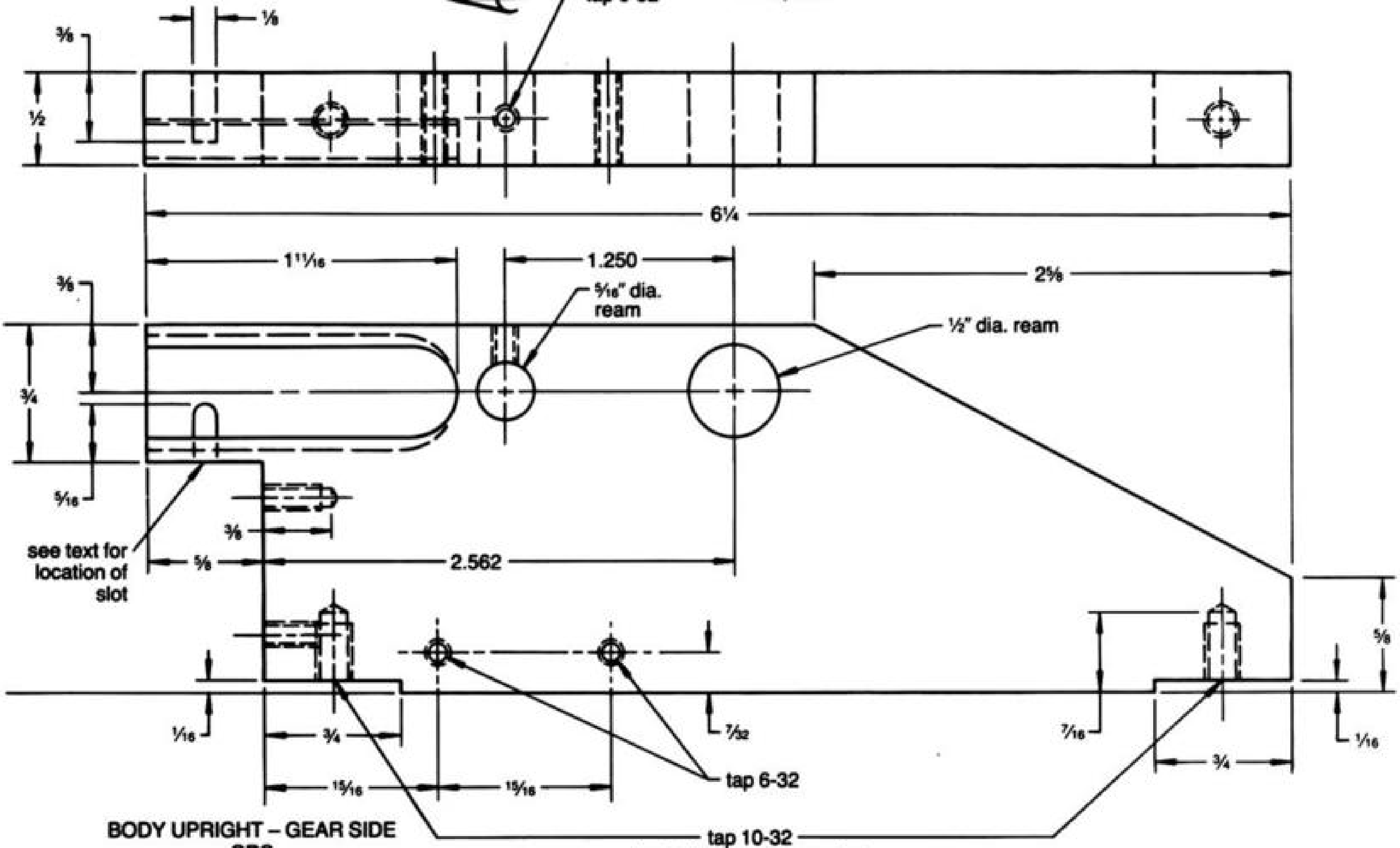
GOVERNOR SIDE FLYWHEEL SHAFT
CRS
1 required


.502" dia.
.376" dia.
9⁄16

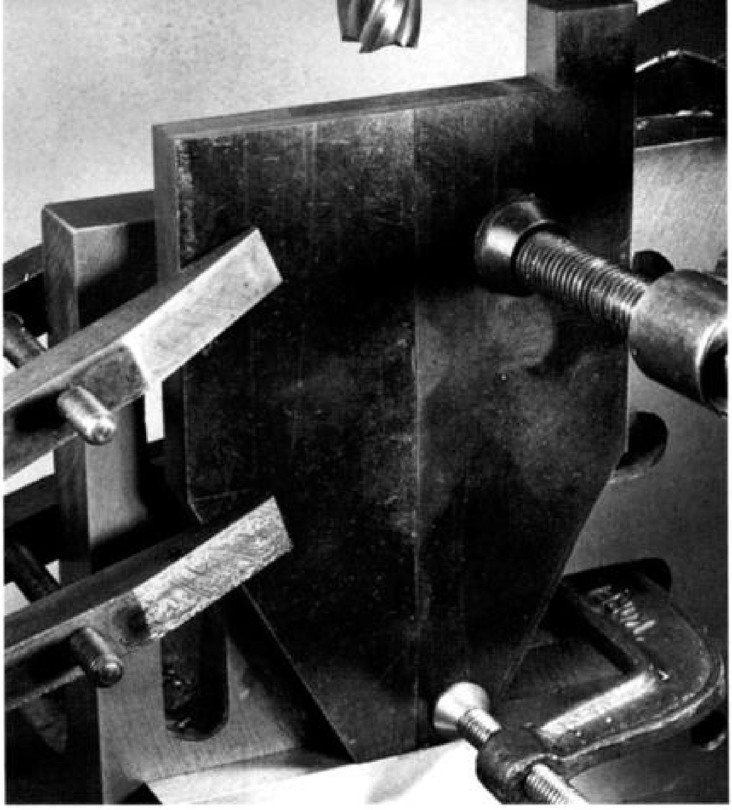
SINTERED BRONZE BUSHING
2 required


5/16" dia. ream
7/16" dia. balance hole
2 places
1 5/32" R
37°
37°
4½" dia.
3/8" dia. ream
17/32
13/16
3/4" dia.
1/4
45°
15/32

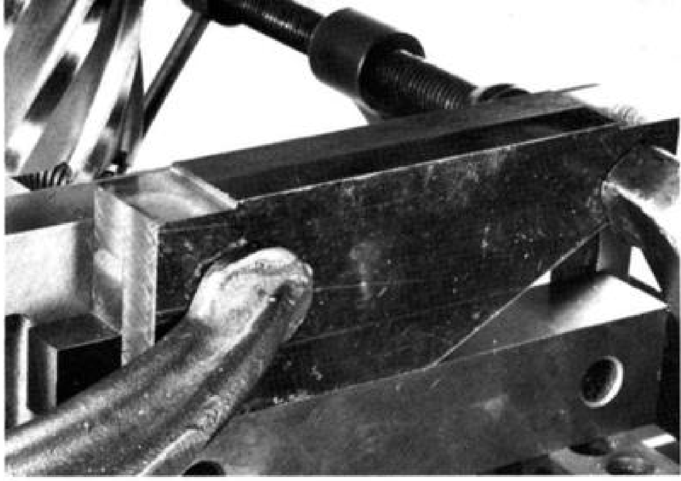
FLYWHEEL
HRS or CRS
2 required


tap 6-32
1/8
3/8
1/2
6¼
1 11/16
1.250
2⅝
5/16" dia.
ream
½" dia. ream
3/8
3/4
5/16
3/8
see text for
location of
slot
5/8
2.562
5/8
1/16
3/4
7/32
15/16
15/16
tap 6-32
7/16
3/4
1/16
tap 10-32
locate from body cross feet

BODY UPRIGHT – GEAR SIDE
CRS
1 required



1



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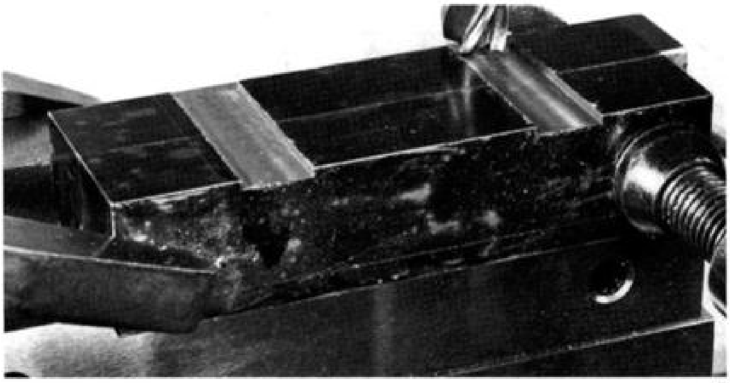

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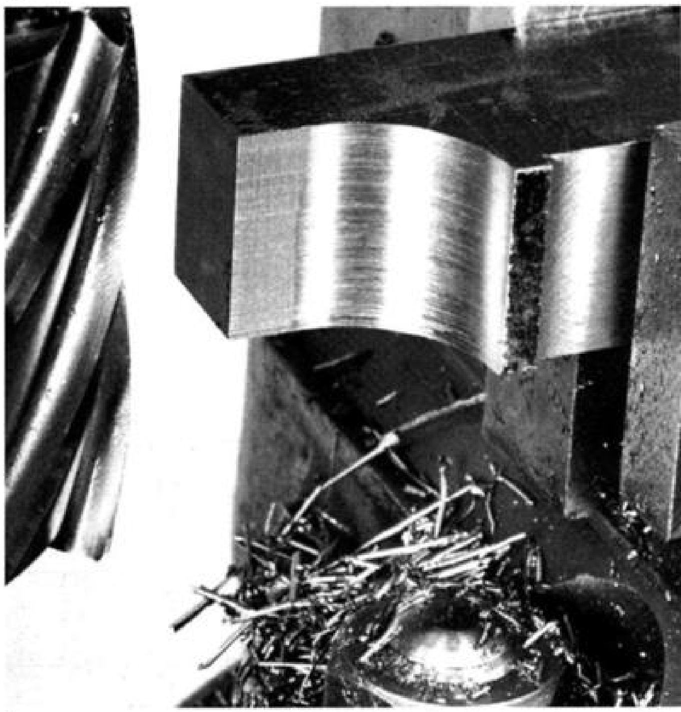
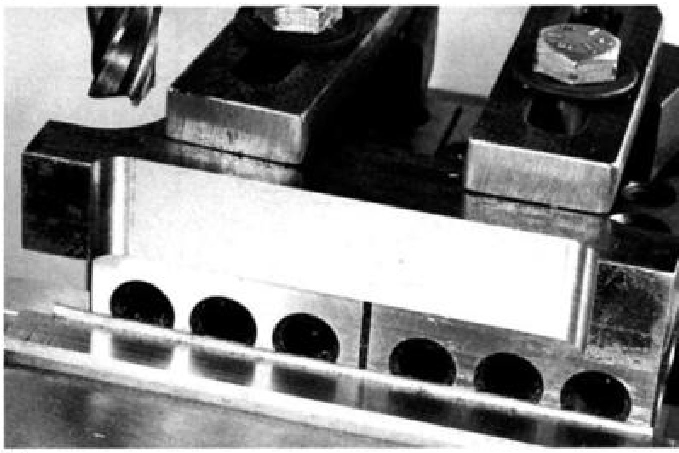


4

coated with layout blue, and carefully scribed with necessary lines for further machining.

If you wish to construct a larger engine than the one specified, merely increase the dimensions by a certain amount, say 25%, etc.

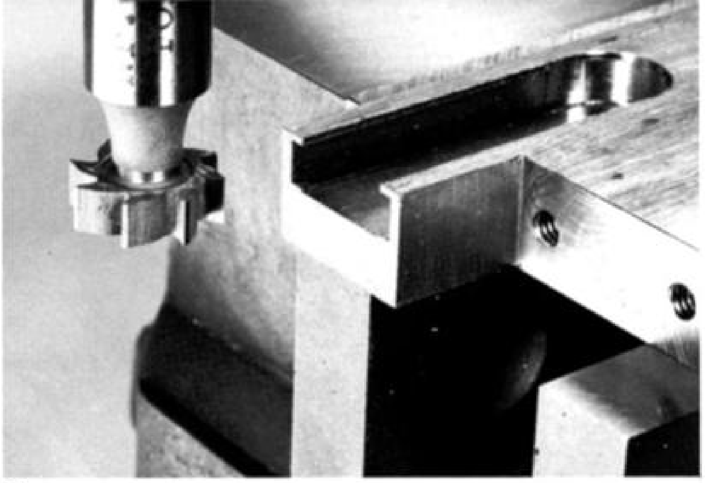
Begin work on the two main Body Uprights (Photo 1). The ends of the plates should be machined square. Now step-cut the bottom edges of the uprights as in Photo 2. These steps will be used to accurately position the two mating cross feet, so maintain the depth of the cuts in the same plane at both ends. Set aside these two pieces for the moment, and begin work on the two cross feet. Mill out the two channels (Photo 3). The width of the channels should be a snug fit for the two uprights, so measure the thickness of the upright plates first. Proceed by forming the radius on each end of the cross feet (Photo 4). Now undercut the base of the feet as in Photo



5

5. The cross feet are now bolted to the body uprights. Mark each cross foot underneath so it will be placed in its identical location every time it has to be assembled or disassembled – which will be quite a few times!

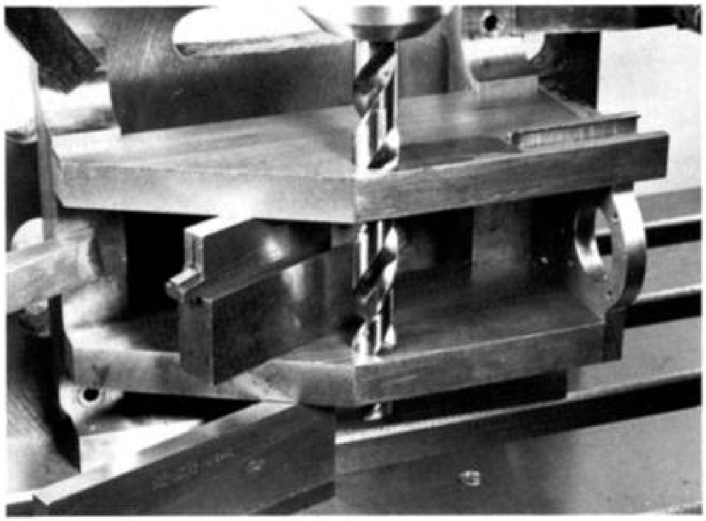
6



7

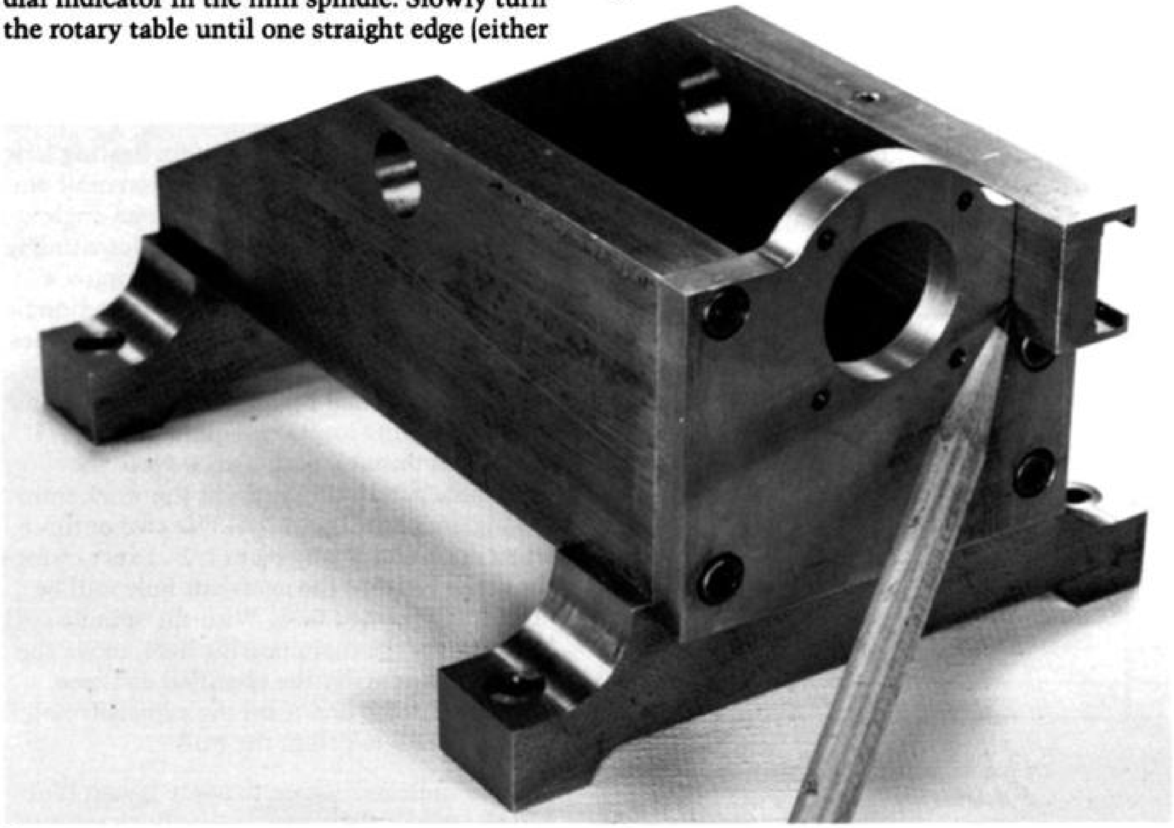
The Body Backplate is next. Lay out the plate, then drill and bore the cylinder locating hole.

Mill out the corner notch so the plate will seat properly onto the rear end of the engine frame unit. Employ a rotary table to form the curved arch on the upper rim of the backplate. First center up the rotary table true to the mill spindle. Use a dial indicator. Now position the hole in the backplate true to the spindle and rotary table. Set the longitudinal and cross slide calibrated collars to zero. Now move the table to one side enough to mill the arch by using the crank on the rotary table. In Photo 6, the arch has been formed.



8

To spot drill the location of the four threaded stud bolt holes in the backplate, chuck up a dial indicator in the mill spindle. Slowly turn the rotary table until one straight edge (either



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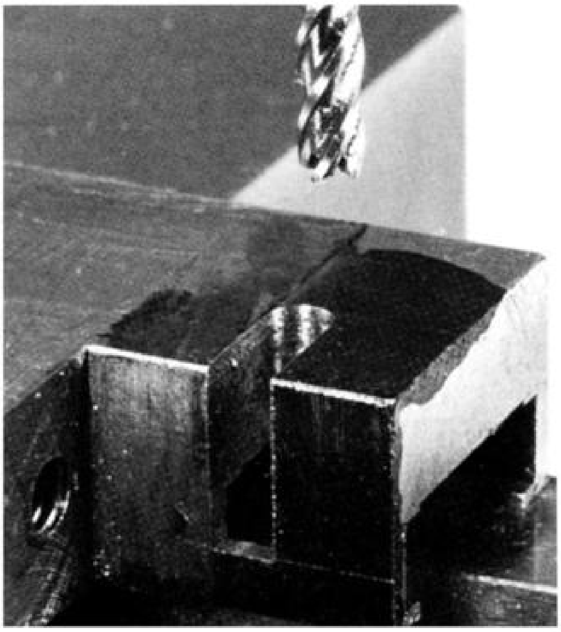

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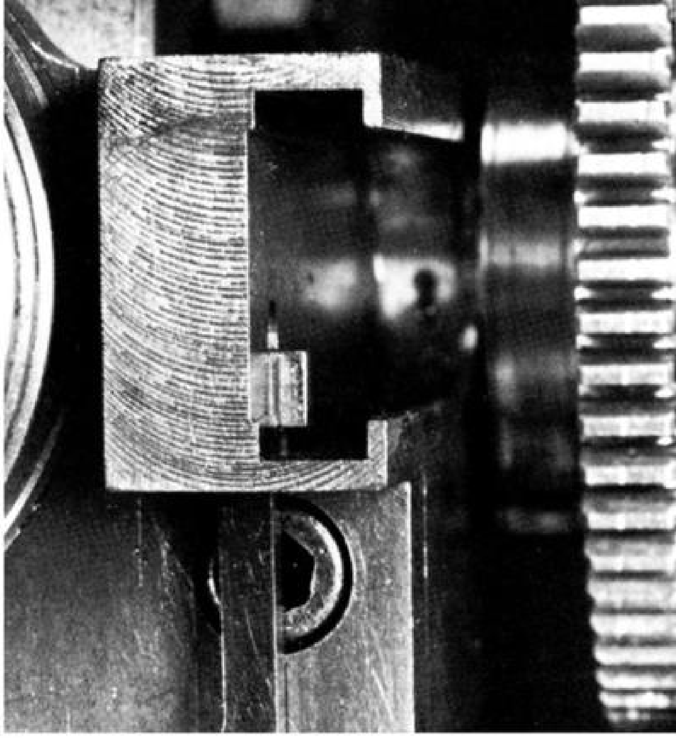
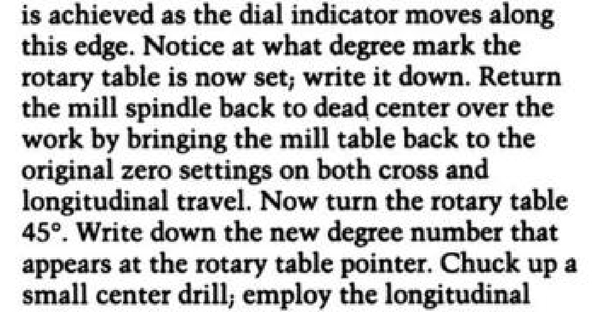


11

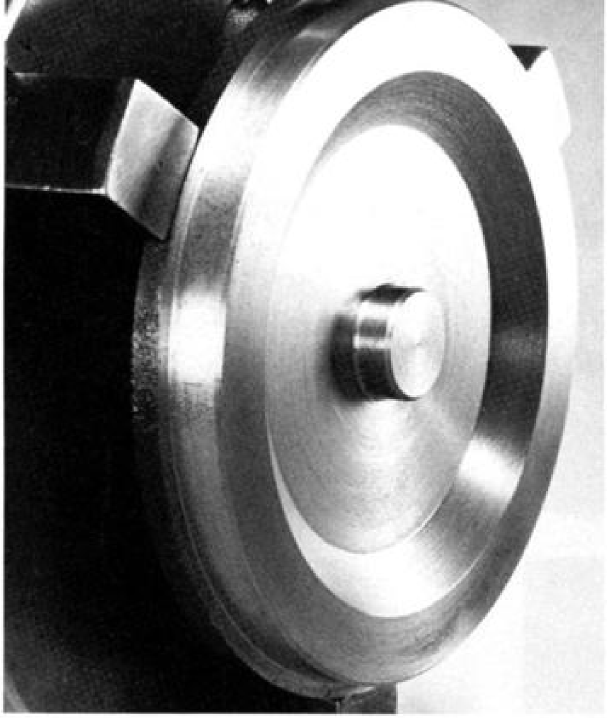
the bottom edge or a side edge surface) of the backplate is fairly well in line (parallel) with the longitudinal table travel. Move the dial indicator along this edge surface. Slowly turn the rotary table and stop when a zero reading is achieved as the dial indicator moves along this edge. Notice at what degree mark the rotary table is now set; write it down. Return the mill spindle back to dead center over the work by bringing the mill table back to the original zero settings on both cross and longitudinal travel. Now turn the rotary table 45°. Write down the new degree number that appears at the rotary table pointer. Chuck up a small center drill; employ the longitudinal table travel to position the center drill the specified distance from the center of the hole. Spot drill the first hole, then turn the rotary table exactly 90°, spot drill, rotate another 90°, etc. Remove the work from the mill and proceed to drill and tap these four holes.

However, do not run the tap completely through the plate. Threaded rods will be used for stud bolts in these holes. Thus, by stopping short of tapping all the way through, it will also prevent the threaded rods from screwing all the way through the plate. Now lay out and drill the four bolt holes that will secure the backplate to the body. Use either socket head screws or flathead screws. Either way, the bolt heads are countersunk flush with the surface. Next, lay out and prepare to mill the exhaust valve push rod guide channel in the body side (Photo 7). Mill a 1/2" wide slot to the specified depth and length. Follow with a 3/16" wide by 5/8" diameter Woodruff key cutter or T-slot cutter.

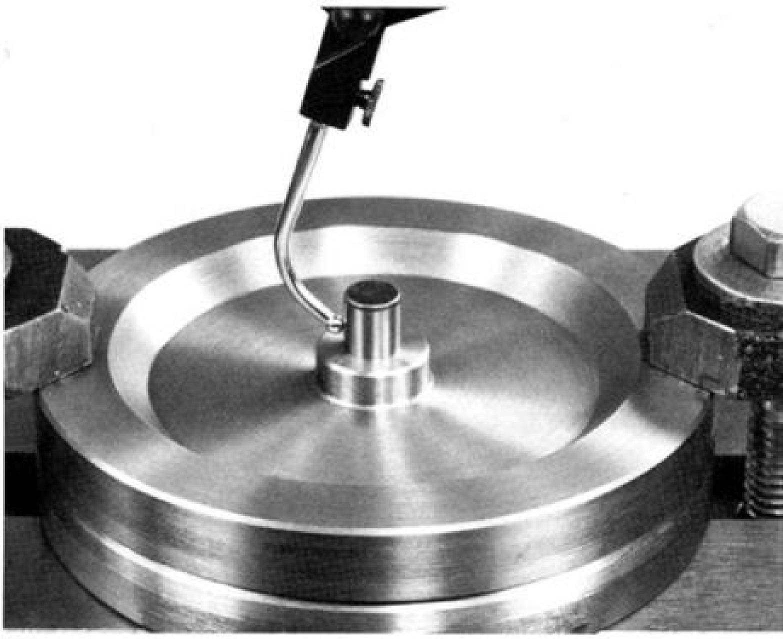


Lay out the location for the main bearing hole on the same body upright. Then assemble the entire body unit. Clamp it against an angle plate that has been trued up to the longitudinal travel of the mill table (Photo 8). Employ a wiggler or center scope to position the spindle directly over the main bearing hole cross lines. Lock the cross slide. Set the calibrated collar on the longitudinal travel to zero, then center drill the bearing location. Follow with a 1/4" drill down through both plates. Note the adjustable parallels to prevent the work from flexing under drill pressure. Use two or three larger drills and finally ream 1/2". Don't change the setup because the camshaft hole will be drilled and reamed next. With the spindle still located over the main bearing hole, move the table longitudinally the specified distance, center drill, drill and ream the camshaft hole. Remove the work from the mill.

Photo 9 indicates where to apply layout blue and to scribe a fine vertical line flush with the



12



13

backplate surface. The body upright is then removed and clamped in the mill vise (Photo 10). Gradually mill the slot so the left-hand side of the slot is flush with the scribed line. Just the tip of the U-shaped "catch pin" arm will be positioned in this slit (Photo 11). When activated by the governor it catches in a slot in the valve push rod.

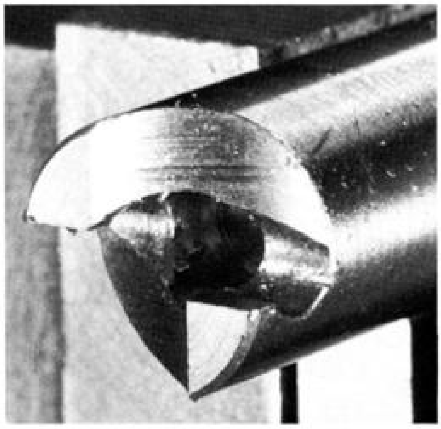
Now set this work aside and proceed to machine the two identical Flywheels. Finish the recessed side first, machining as wide a swath as possible on the outside diameter (Photo 12). Do not drill the shaft hole at this time. Remove the wheel and install it in a four-jaw chuck with the opposite side outward. Insert the wheel only a short distance into the jaws because a clearance space between the chuck jaws and the yet unmachined portion of the wheel blank is needed for dial indicating. True up the machined diameter of the wheel fairly well, then adjust the indicator probe to bear sideways against the shoulder that has been formed by machining the blank down to wheel size. When this face is running true, again check the outside diameter and true it up. This side of the wheel is machined just plain flat. Finally, center drill, then carefully drill through with a 3/16" drill, following with two or three larger drills to increase the hole to 23/64". Now drill through with a "U" drill and finish bore it to size.

After machining both flywheels, mount them flat side to flat side in the mill as indicated in Photo 13. Insert a close fitting short length of 3/8" rod or dowel pin through both shaft holes. Use a dial indicator to position the shaft accurately in line with the mill spindle. Lock the cross slide. Set the calibrated collar on the longitudinal travel to zero. Now, to locate the crankpin hole, move the table the specified distance and carefully drill and ream through both flywheels. Remove the work, and lay out the location for the two balance holes adjacent to the crank hole. These holes can be drilled in the drill press – nothing critical about them, merely insert dowel pins in the shaft hole and the crank hole, clamp them together and drill both flywheels at the same time.

Machine the two Crankshaft Rods and the Crank Rod. All three should be machined between centers. Also, the threads on the crank rod should be cut in the lathe.

Now is the time to decide if you want the optional Self-ejecting Hand Crank for your engine. It's handy, but not absolutely necessary. The motor can be started by gripping one of the flywheels with your fingers and giving it a whirl. Refer to Photo 14 for a closeup of the crank seat that would be machined on the outer end of the longer flywheel shaft. You may wish to practice first on a scrap piece of 3/8" rod before tackling the real engine shaft.

Drill a 5/32" hole about 1/4" deep into the end of the shaft. If you have an indexing head for the mill that will hold the shaft, use it. If not, clamp the shaft in the mill vise as in Photo 15. A 1/8" diameter crosshole is about to be drilled accurately down through the rod and as close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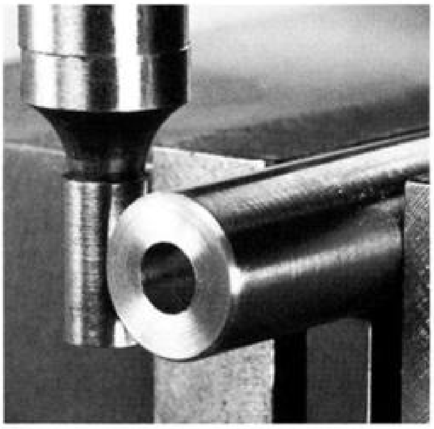
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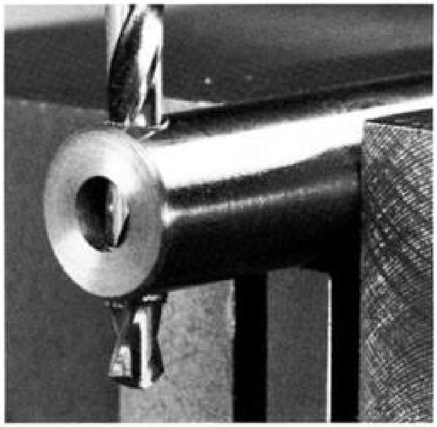
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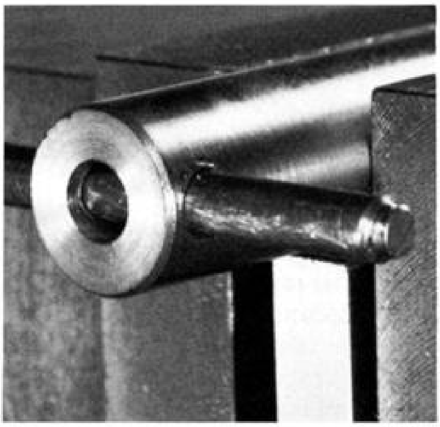
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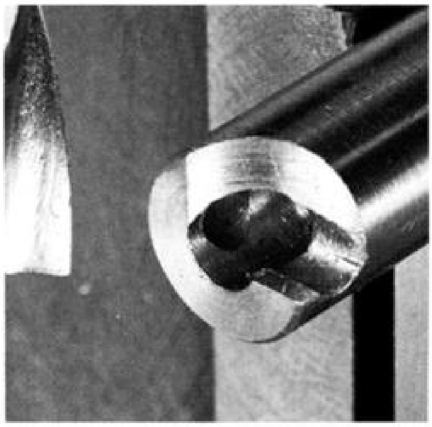
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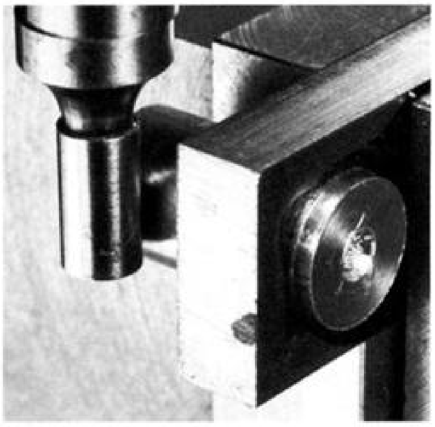
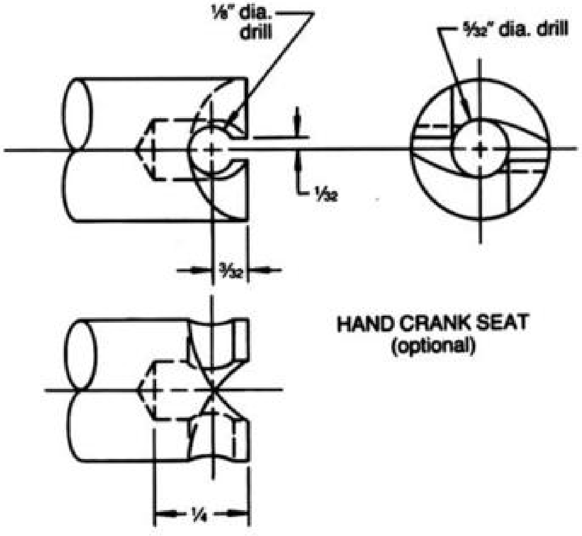
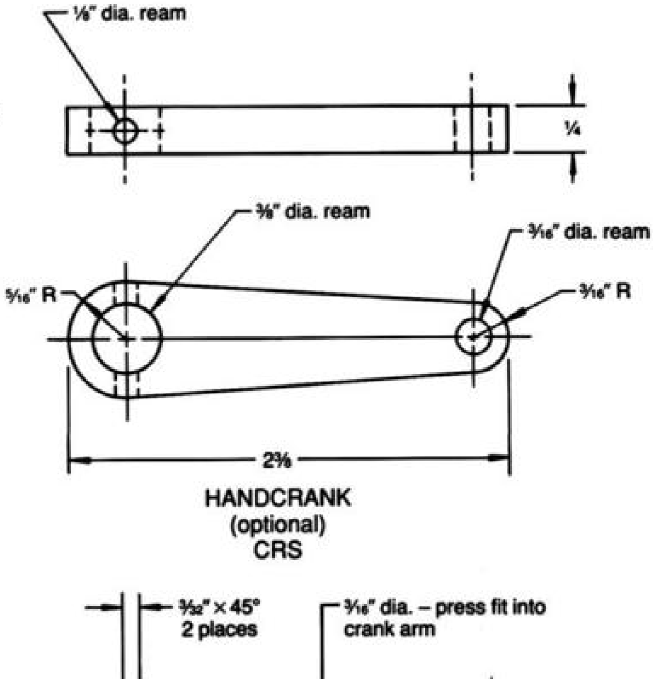

19

to the center line as possible. Use an edge finder. Then center drill and follow with a 1/8" drill (Photo 16).

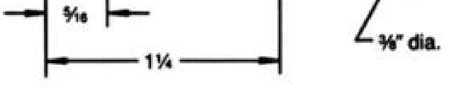
Loosen the shaft in the vise and rotate it about 90°. Insert a short length of 1/8" rod through the crosshole (Photo 17). Adjust the shaft until the 1/8" rod is as close to a true horizontal position as possible, then lock the vise. Install a 5/8" diameter end mill in the spindle. Do not use an end mill smaller than

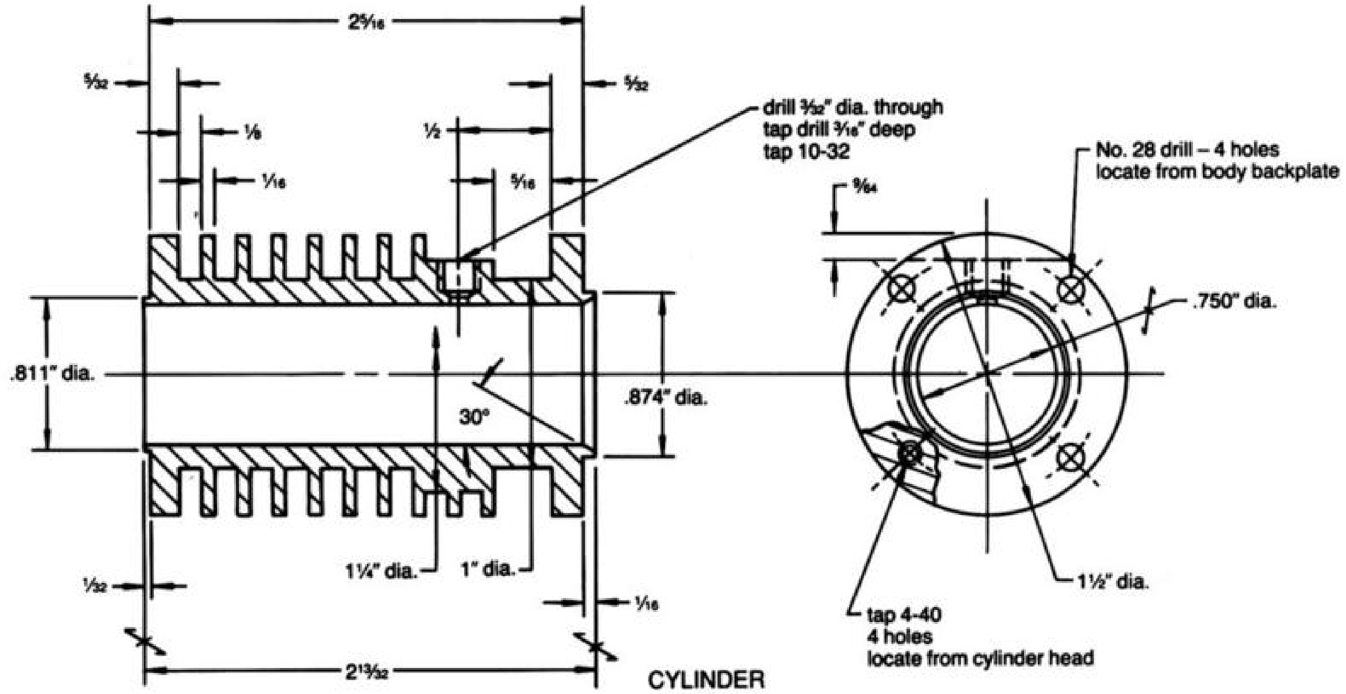

1/8" dia. drill
5/32" dia. drill
1/32
3/32
1/4

HAND CRANK SEAT
(optional)

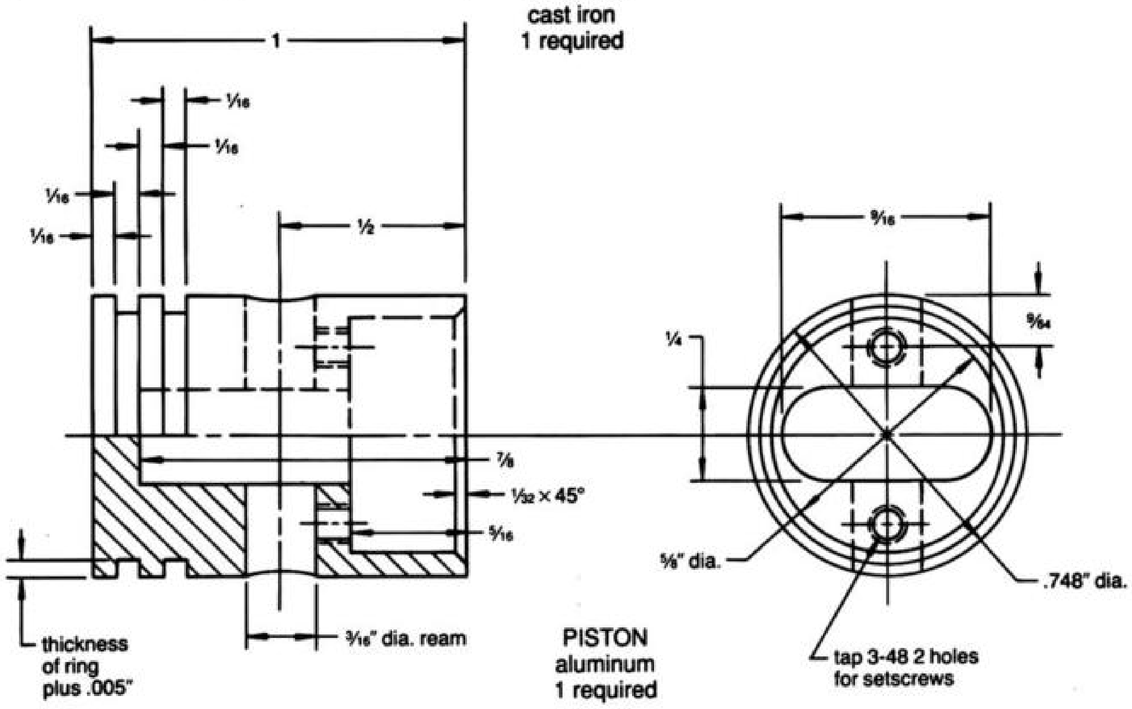

1/8" dia. ream
1/4
3/8" dia. ream
3/16" dia. ream
5/16" R
3/16" R
2 3/8

HANDCRANK
(optional)
CRS

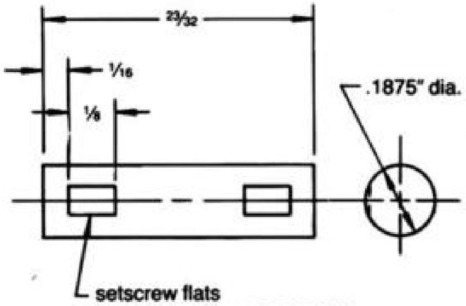

3/32" × 45°
2 places
3/16" dia. – press fit into crank arm
5/16
1 1/4
3/8" dia.


2 5/16
5/32
5/32
1/8
1/2
drill 3/32" dia. through
tap drill 3/16" deep
tap 10-32
1/16
5/16
No. 28 drill – 4 holes
locate from body backplate
9/64
.750" dia.
.811" dia.
.874" dia.
30°
1 1/4" dia.
1" dia.
1/32
1/16
1 1/2" dia.
tap 4-40
4 holes
locate from cylinder head
2 13/32

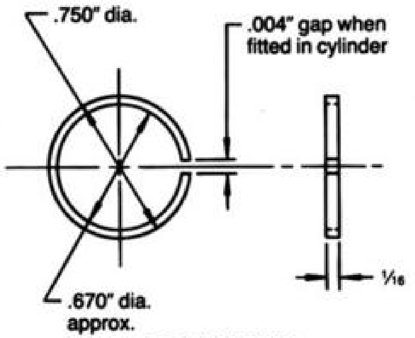
CYLINDER
cast iron
1 required


1
1/16
1/16
1/16
1/16
1/2
9/16
9/64
1/4
7/8
1/32 × 45°
5/16
5/8" dia.
.748" dia.
thickness
of ring
plus .005"
3/16" dia. ream
tap 3-48 2 holes
for setscrews

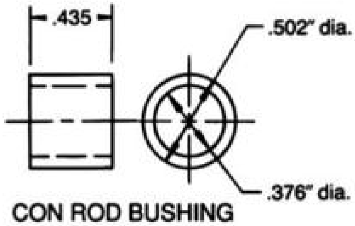
PISTON
aluminum
1 required


23/32
1/16
1/8
.1875" dia.
setscrew flats

WRIST PIN
drill rod
1 required


.750" dia.
.004" gap when
fitted in cylinder
.670" dia.
approx.
1/16

PISTON RING
cast iron
2 required


.435
.502" dia.
.376" dia.

CON ROD BUSHING
sintered bronze
1 required

5/8" or larger than 21/32". Now refer to Photo 18. First lower the end mill in front of the shaft until its cutting tip is 1/32" below the shaft center line. Then slowly and carefully mill the radius on the end of the shaft. Employ both the longitudinal feed and cross-feed at the same time to accomplish this. The idea is to bring the left side of the curve at the outer end of the shaft flush with the side of the 5/32" hole. The right-hand side of the curve is machined flush to the back side of the 1/8" crosshole.

This setup is for a clockwise rotation of the engine as viewed from the gear side of the motor. If you plan on having your motor revolve in an counterclockwise direction, mill the curve from the opposite side of the shaft. After milling the first radius, insert the 1/8" rod in the crosshole, loosen the vise, revolve the work 180° and lock the vise. Mill the second curve. Remove the work. A small round file is employed to round off all sharp edges inside and out of the configuration. File until a short length of 1/8" rod can be inserted crossways into the slot with a clockwise motion until it seats into what's left of the crosshole. The two large curves are what eject the hand crank from the shaft as soon as the engine fires. So if there's any binding between the crank and its seat on the shaft, the crank won't eject properly and the result is a whirling crank, which might fly off at any moment! The crank itself is easily constructed. Cut the bar stock to length, lay out, drill and ream the 3/16" and 3/8" holes. Use care when drilling and reaming the 1/8" crosshole through the 3/8" hole (Photo 19). Insert a snug fitting piece of rod through the larger hole and employ an edge finder to locate the true center line of the hole. Then drill and ream the 1/8" crosshole through the center line of the bar and the hole. Either a 1/8" hardened dowel pin or drill rod could be used for the cross pin. A light press fit is ideal for holding the pin in place. Otherwise, solder it in position. Check to make certain that the finished crank arm fits snugly but freely onto the shaft. A thin layer of oil will help.

20

Now proceed to press fit the two main shafts into the flywheels. After pressing, and just to play safe, drill a 3/32" hole – whose diameter is half in the shaft and half in the flywheel. Press in a roll pin to lock everything in place (Photo 20) and then cut it off flush to the surface. The flywheel with the longest shaft will be positioned towards the gear side of the motor; press fit the con rod crank journal into the flat side of this flywheel. The remaining end of the crank journal is not pressed into the other flywheel; it should just be a very snug fit in the hole so the two flywheels may be separated without great effort. Assemble the whole flywheel unit and tighten both crank journal nuts. Measure carefully the distance between the outer face of one flywheel to the outer face of the other; write down the result, then set the flywheel unit aside for a time.

Assemble the engine body unit completely. Measure the distance between the two main bearing holes in the body uprights. Write down this measurement. Now subtract the previous flywheel measurement from the body measurement. The difference should be about 1/16". Whatever it is, it means that half of that amount is the distance for each bearing to extend into the space between the two body uprights – minus, of course, 3 or 4 thousandths for end play clearance against the flywheel hubs. Disassemble the two body uprights and press in the bronze bushings. Reassemble the body and run a sharp 3/8" reamer through both bearing holes. Once again, unbolt the two body uprights.

Returning to the flywheel unit, loosen the crank journal nut on the governor side flywheel (the one with the shortest flywheel shaft). Assemble the body unit with the main shafts and flywheels in place. Tighten all of the body bolts, including the body backplate, and then tighten the loose crank journal nut. Rotate the flywheel and check for binding. If it binds somewhat, check for sufficient end play between the main bearing sleeves and the flywheels; it could also indicate that the main bearings are too tight on the shafts, or slightly misaligned. Whatever the reason, it will have to be corrected; perhaps a little scraping inside the bearing sleeves on the high spots will do the trick. If there's only a minor amount of drag on the flywheel, ignore it, as the engine can be "run-in" later on.

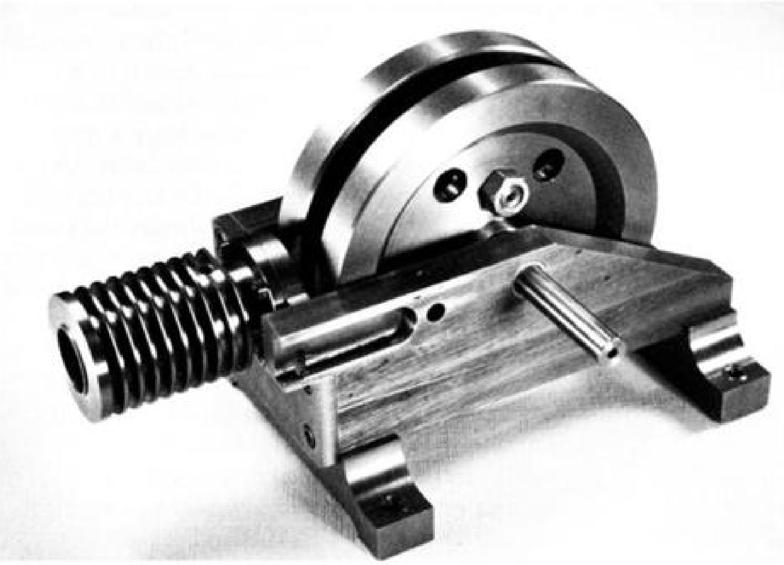
Photo 21 shows the nearly completed cylinder bolted to the engine frame. Begin work on the Cylinder by facing off the end of your cast iron stock piece and drilling the center hole for the tailstock support. Machine the stock piece to a diameter of 1-1/2". For machining the fin slots, grind a square nosed tool bit to a width close to .125", and long enough to clear the 1/4" deep cuts. The front cutting angle on the tool should be kept to a minimum to avoid chattering. Prepare to machine the 5/16" wide slot (Photo 22) near the cylinder base which is the end supported by the tailstock. Swing the compound slide around parallel to the spindle. Crank the slide towards the tailstock about as far as it will travel. Clamp the tool bit in position, then bring its cutting edge to just touch the OD of the cylinder blank.

Now set the calibrated collar on the cross slide to zero. Move the carriage to bring the right-hand side of the tool 7/32" away from the outer end of the work. Lock the carriage; this position will allow just enough material to step-cut the 1/16" long locating shoulder on the bottom end of the cylinder later on. Begin cutting the groove; use the slowest spindle speed on the lathe – and no cutting oil! Watch the cross slide dial, and when it reaches .250", back out the tool. Move the carriage or compound slide to the left about an 1/8" and begin cutting again, feeding in .250". Repeat the operations until the groove is the correct width.

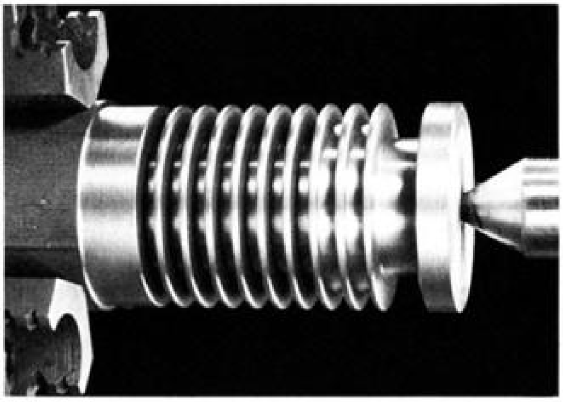
Now for the Fins. Position the carriage so the left side of the tool is lightly touching the left side face of the groove just finished. Set the calibrated collar on the compound slide to zero. Lock the carriage. Back out the tool to clear the cylinder. Advance the compound slide to the left .125" plus the thickness of the fin, or a total of .187" for each cut. Then immediately reset the calibrated collar on the compound back to zero; do this every time before cutting the next groove. Note that the first two 1/8" wide grooves are machined only 1/8" deep. The remaining grooves are 1/4" deep.

After cutting the fins, drill and bore the cylinder. The depth of the bore should be about 1/8" longer than the total length of the cylinder for easy cutoff. Machine the ID as smooth and straight as possible. Machine the little step-cut on the outer end of the cylinder about .001" smaller than the diameter of the hole in the body backplate. Cut off the cylinder from the stock piece leaving sufficient material on that end for the 1/32" step-cut to be machined on it. After completion, use the four threaded holes in the engine backplate to locate the holes in the cylinder base flange.

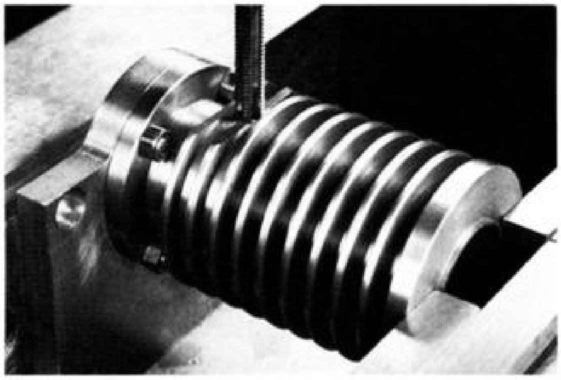
Bolt the cylinder to the engine backplate and clamp both in the mill vise (Photo 23). Mill the first two fins flat down to the depth of the 1/8" grooves; then center drill for the oil cup location. Follow with a 3/32" drill through the cylinder wall, counterbore with a No. 21 drill to a depth of 3/16", and tap 10-32.



21



22



23

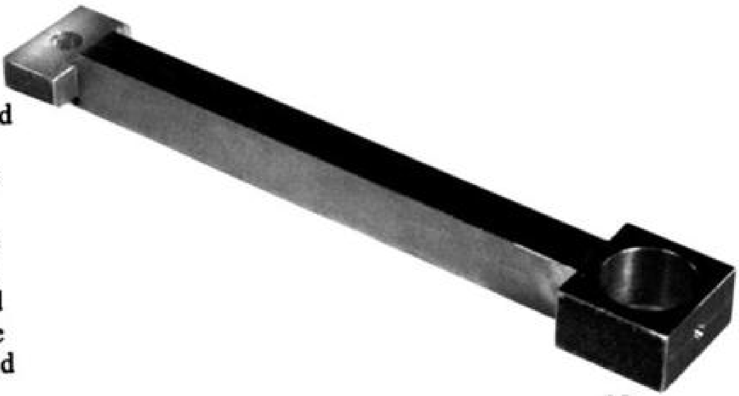
Of course, the cylinder bore should be lapped. Machine a steel rod .002" smaller than the cylinder bore. It should extend outward from the chuck about 1/2" longer than the cylinder length. slightly undercut a portion of the rod extending outward from the chuck until the actual "business" portion of the lapping rod is about 3/8" shorter than the length of the cylinder. Apply fine grit valve grinding compound on the rod and in the cylinder.

Attempt to slide the twist the cylinder onto the rod. If it's too tight, wipe off the compound from the rod and machine off another .001". Apply more grinding compound and slide the cylinder onto the lapping tool. Keep a firm grip on the cylinder and start the lathe. Use a fairly slow spindle speed. As the lapping tool revolves, slide and turn the cylinder back and forth along the rod about 3/8". After a minute or so, stop the machine. Apply more compound and resume the procedure. After a couple of minutes, remove the cylinder and carefully clean all of the grit from its surface. An old toothbrush and solvent will help. Normally, lapping will remove only about .0001" or .0002" from the bore, so don't expect to straighten out a tapered cylinder or roughly machined bore by this method.

Use either cast aluminum or tempered aluminum rod for the Piston. Let the rod extend outward from the chuck about 1-1/2". Face off the end, and machine the OD to size. Carefully cut the ring grooves. Center drill the end face and drill a 1/4" hole to equal the depth of the upcoming con rod slot. Then counterbore the outer end of the piston. If the overall length of your aluminum stock piece is only 3" or 4" in length, leave the piston attached to it for the next operation. But if the stock piece is longer than 4", cut the piston off, leaving some extra stock on the piston head for facing off. To mill the con rod slot, clamp the piston vertically in the mill vise. Use at least one V-block to secure it. If the piston is still attached to the stock piece, then clamp the V-block on the stock piece. Use a dial indicator to center the piston directly beneath the mill spindle. Employ a long 1/4" end mill and gradually cut down to form the slot. To eliminate chips from piling up in the cavity, direct the air blast from an ordinary vacuum cleaner at the piston. Wear goggles.

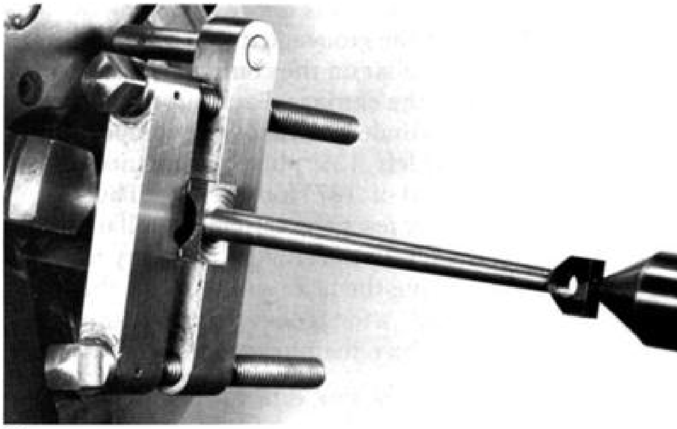
Finally, drill and ream the wrist pin hole, then drill and tap for the setscrews. The completed piston is shown in Photo 24. Now check to see if the piston rings will fit into the ring grooves. Attempt to insert a segment of the ring OD into the ring groove. If it's too tight, lay a sheet of fine emery paper face up on a flat surface and lightly sand the ring on each side. Keep checking for a free fit, but not a sloppy fit. You should be able to roll the ring around in the piston groove without any binding.

24


25

Begin work on the Connecting Rod by cutting the stock piece to the proper width, thickness, and length. Lay out center lines for the wrist pin and crank journal holes, and also for the small center drill hole at each end of the piece which later, on the final machining, will be completed between centers in the lathe.

To center drill each end of the blank, square it vertically in the mill vise, and with the aid of a wiggler, locate the mill spindle directly over the center lines. After center drilling both ends, lay the workpiece flat in the vise. Drill

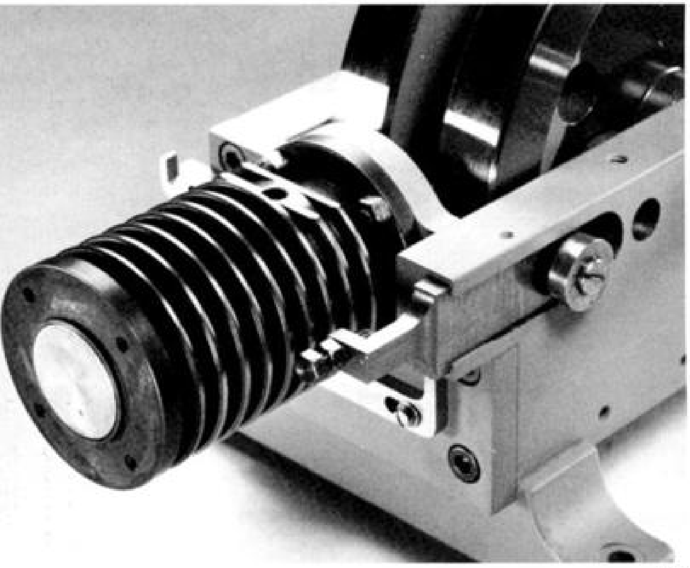

26

27

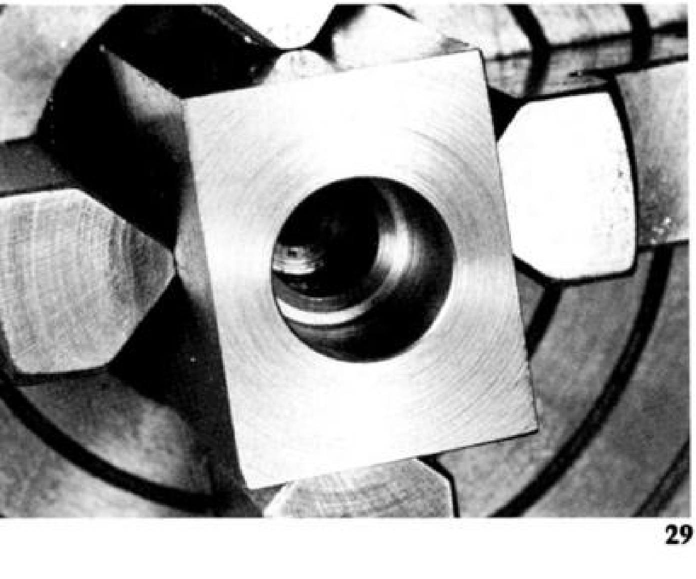
and ream both holes. With the aid of an end mill, step-cut the wrist pin end of the blank down to its proper thickness; equal amounts of material are removed from each side of the blank. The step-cut is visible in Photo 25. To eliminate some excess material, also rough-cut the main body section. Now mount the work between centers in the lathe, as in Photo 26.

Okay! If the con rod is supposed to be between centers, what the heck is that chuck doing in the picture? Simple, it's holding the center! I find it more expedient and accurate to chuck up a piece of rod and machine the 60° taper on it than to bother removing the chuck, cleaning out the spindle hole, etc.

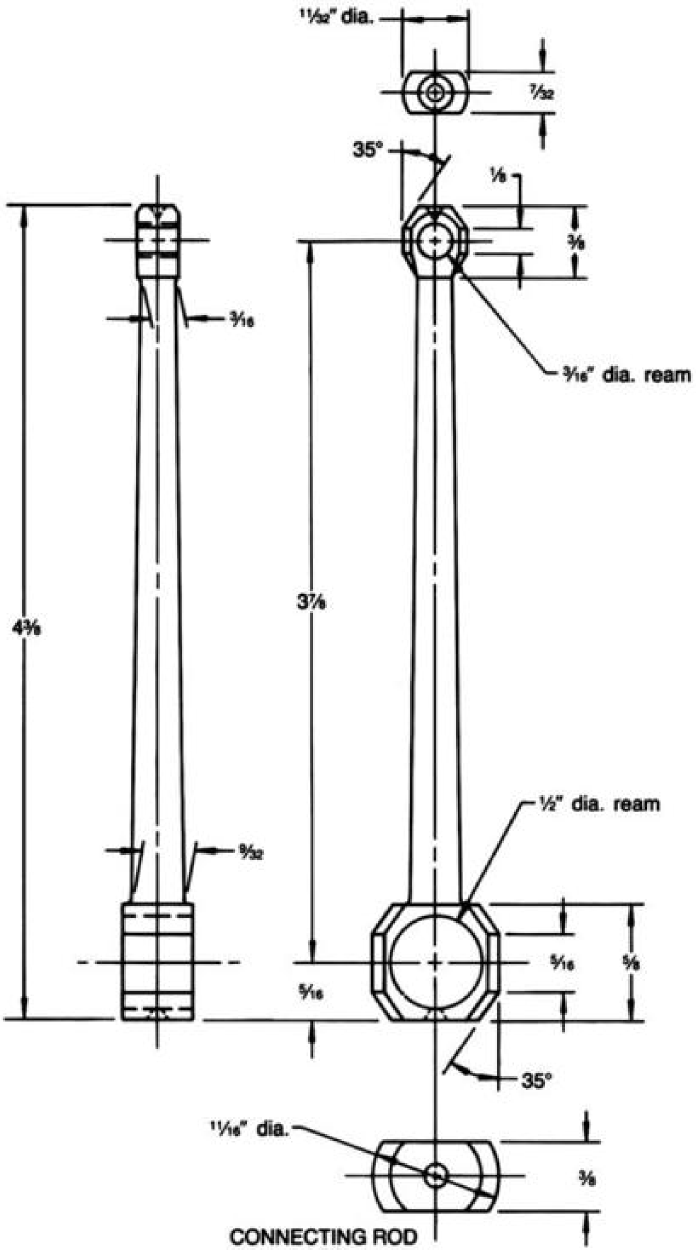
Now offset the tailstock roughly 1/16" towards you. Begin machining the long taper. As you approach the correct diameter at one end of the taper, check the diameter at the other end to verify that it is also the correct diameter.



28



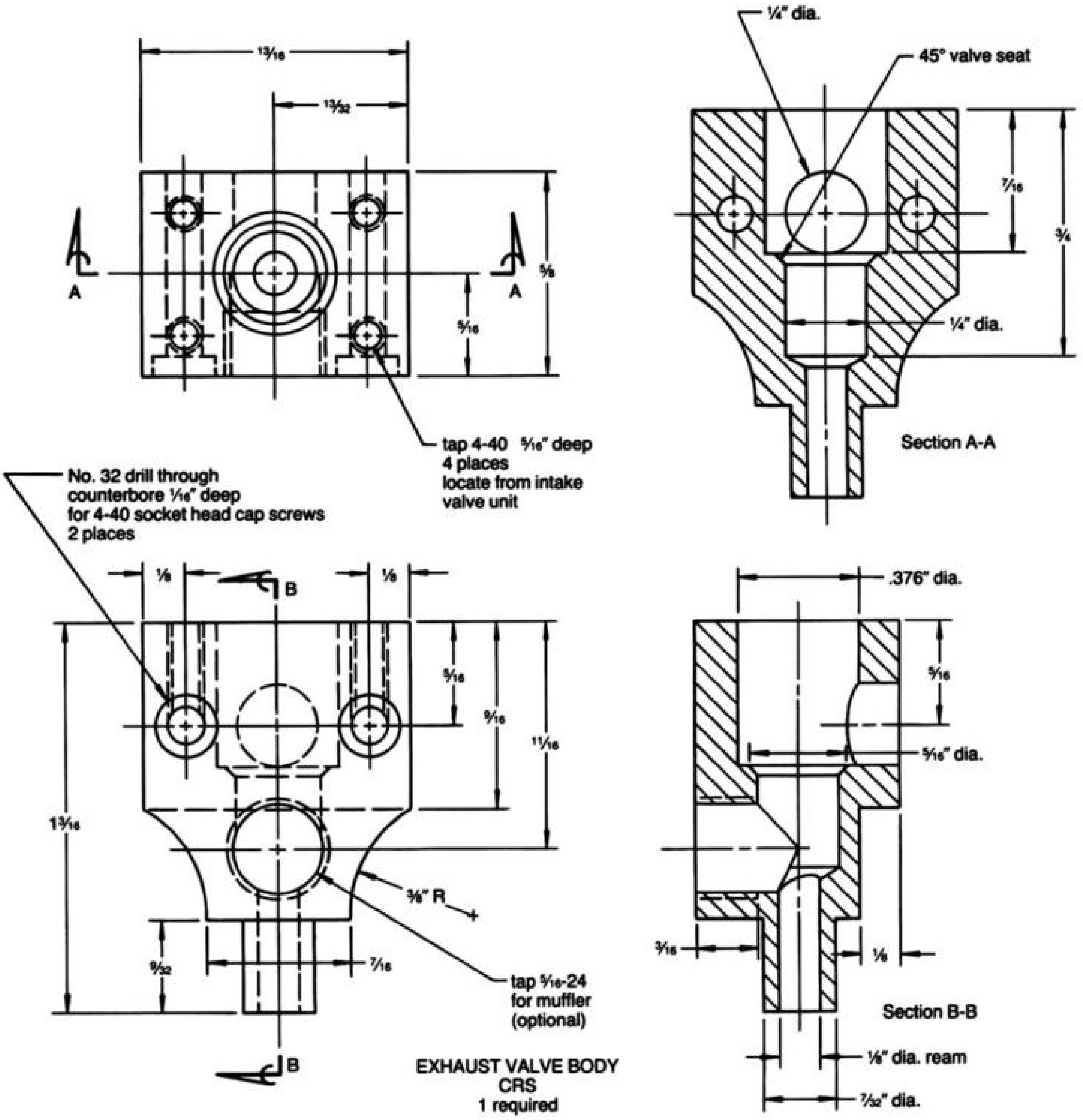
29



CONNECTING ROD
CRS
1 required

Adjust the tailstock if needed. Upon completion of the taper, reset the tailstock to zero. Remove the work from the dog and insert the wrist pin end of the con rod into it. Now form the crank throw end as visible in Photo 27.

Once more remove the dog, reinsert the crank throw end and complete the machining on the wrist pin end. finally, press the oil impregnated sintered bronze bushing into the crank throw hole. Let it extend an equal amount on each side of the con rod. When the piston and con rod are assembled in the engine, the piston head should be approximately flush with the outer end of the cylinder at the top of the stroke (Photo 28).


13/16
13/32
A
A
5/8
5/16
tap 4-40 5/16" deep
4 places
locate from intake
valve unit
No. 32 drill through
counterbore 1/16" deep
for 4-40 socket head cap screws
2 places
1/8
B
1/8
5/16
9/16
11/16
1 3/16
3/8" R
7/16
9/32
tap 5/16-24
for muffler
(optional)
B
1/4" dia.
45° valve seat
7/16
3/4
1/4" dia.
Section A-A
.376" dia.
5/16
5/16" dia.
3/16
1/8
Section B-B
1/8" dia. ream
7/32" dia.

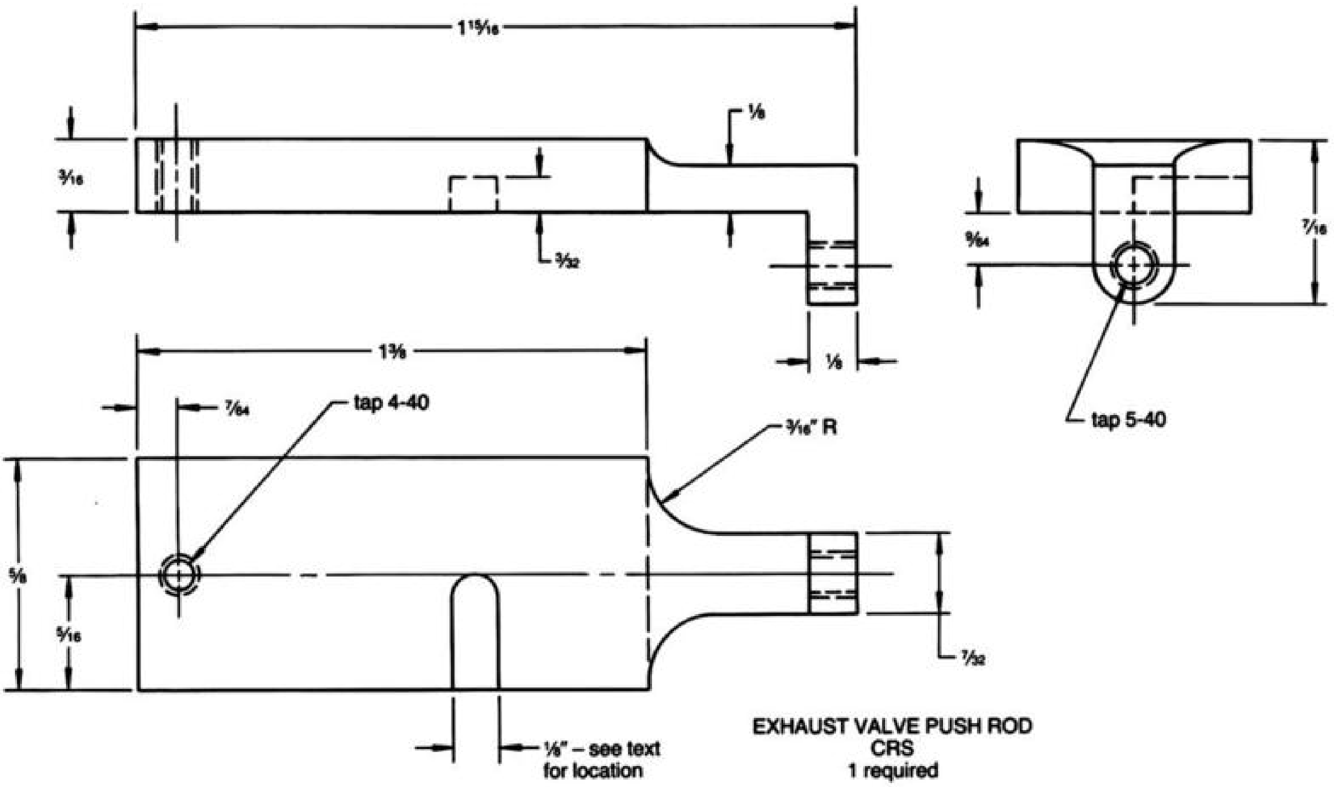
EXHAUST VALVE BODY
CRS
1 required

Prepare a block of steel for the Exhaust Valve Body. Scribe all of the center lines for the holes. Mount the work in a four-jaw chuck and center it up to machine the exhaust valve cavity. Use a small center drill and carefully spot the location. Insert a 7/64" drill in the tailstock, and gently and slowly drill the hole through the block. Use cutting oil, and repeatedly back out the drill to clear it of chips. We don't want a wobbly hole!

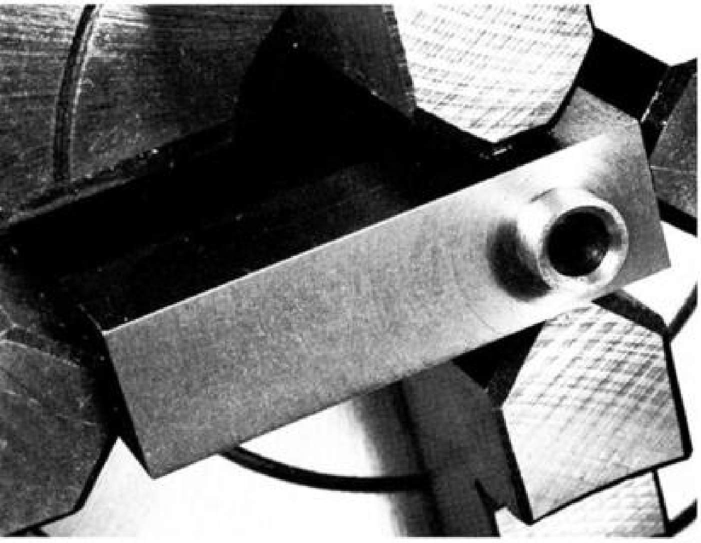
Counterbore with a 1/4" drill to the proper depth. Enlarge the outer end of the hole by using a 23/64" drill, stopping short of the required depth. Install a small boring tool and machine this bore to .376" and bring it to the proper depth. The shoulder at the inner end should be square (Photo 29).

Now machine the 45° valve seat, visible in the photo as the darker segment of the ring. Use cutting oil and carefully ream to 1/8" what's left of the original hole through the block. Remove the work, drill the port hole and the two bolt holes, then drill and tap the exhaust hole. Mill the remaining contours on the block and then set the unit aside.

Prepare the steel blank for the Intake Valve section. Lay out the lines for the valve seat hole and also for the intake "pipe" hole on one end of the blank. Chuck up the piece, as in Photo 30, and machine off the face of the work to form the cylindrical protrusion. Center drill and carefully drill a 7/64" hole through the block. This procedure is similar


1 15/16
1/8
3/16
3/32
1/8
9/64
7/16
tap 5-40
1 3/8
7/64
tap 4-40
3/16" R
5/8
5/16
7/32
1/8" – see text for location

EXHAUST VALVE PUSH ROD
CRS
1 required

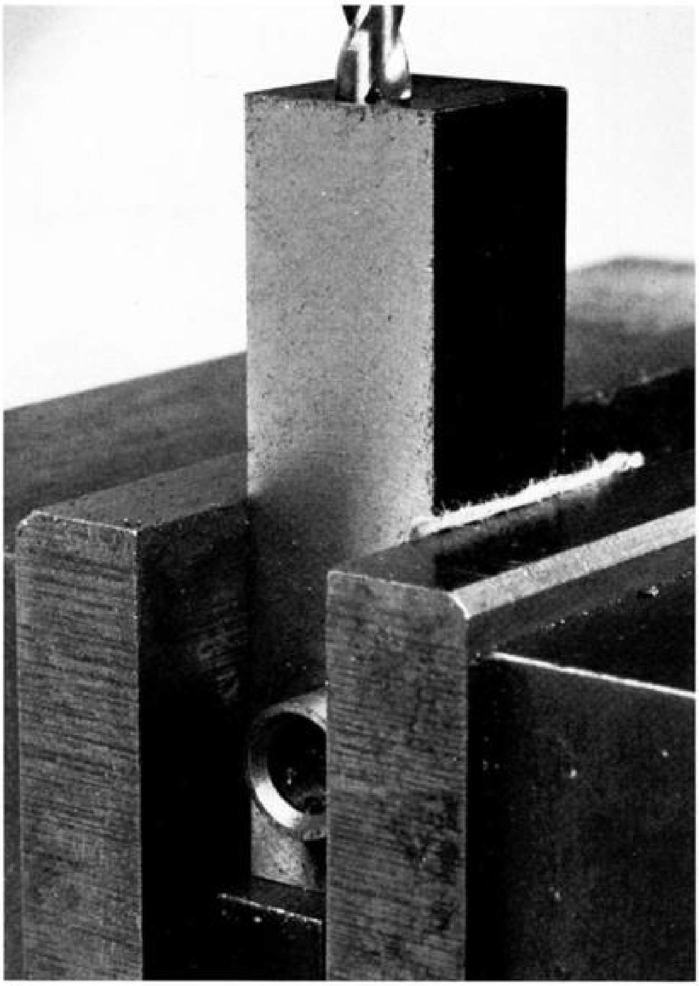


30

to that for the exhaust valve unit except that the 45° intake valve seat is on the outer end of the protrusion.

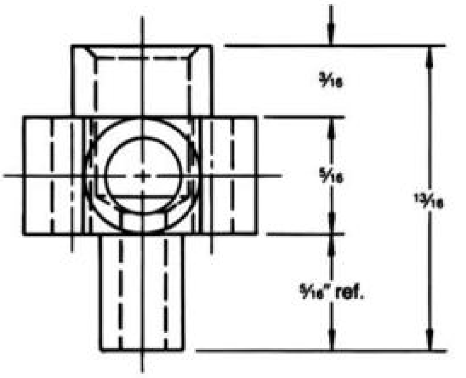
Be sure and run a 1/8" reamer through the work before removal from the chuck. Now mount the piece truly vertical in the mill vise (Photo 31) and drill the 13/64" intake hole down to meet the valve cross hole.

Reposition the unit back in the four-jaw lathe chuck with the opposite side of the surface just machined facing outward. Adjust the chuck until the exposed 1/8" valve stem hole



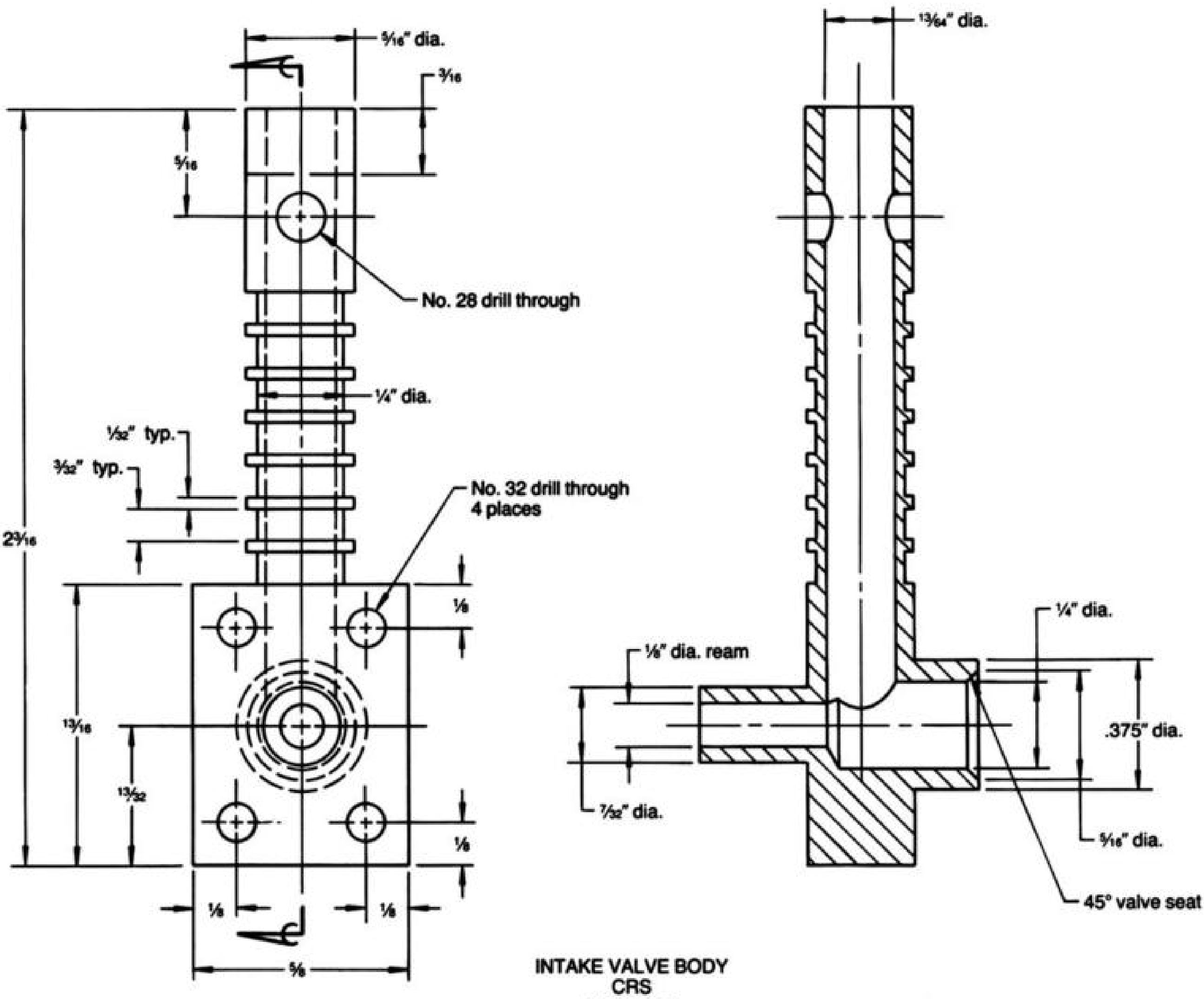
31

is running fairly true. Now machine this side of the work until the valve stem guide has been formed. Remove the work; lay out and drill the four bolt holes and also the cross hole near the outer end of the intake pipe section. Return to the mill and step-cut the unit on each side to form the 5/16" square intake pipe. Then go back to the lathe and the four-jaw chuck. Mount the work, as in Photo 32. True up the piece as close as you can, then cut the cooling fins along the intake pipe. These fins are essential to help prevent vapor lock in the gas line.

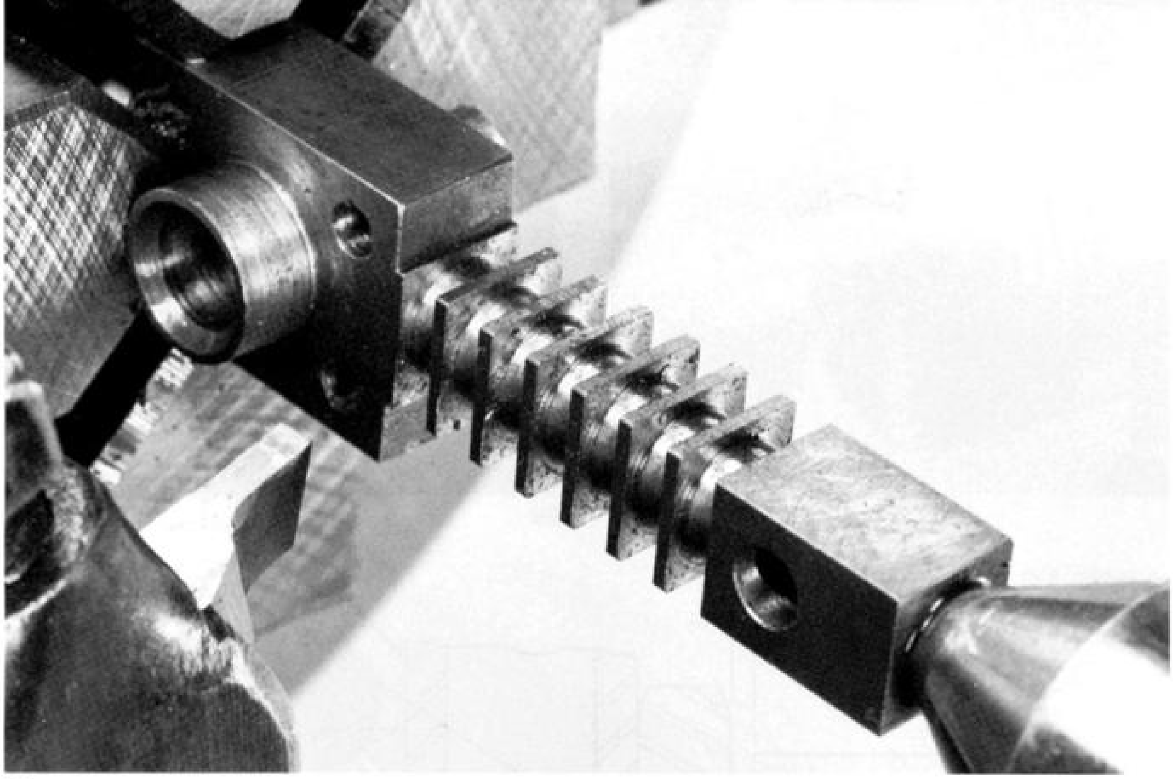

3/16
5/16
13/16
5/16" ref.

When machining the valves, it's advisable to make the stem about 1/8" longer than the plans specify; the end can be cut off later to eliminate the tailstock support center hole from the shaft. Leave the stem diameter about .0005" oversize and polish with fine emery paper for a snug, but free, fit into the valve guide hole. When lapping the valve seats, use the finest grit valve grinding compound available – the finer the better. Don't allow any grit to reach the valve stem! After grinding, examine each valve seat; use a magnifying lens. Each seat should have a uniform gray appearance all the way around; if not, continue lapping.

The Carburetor Jet and Needle Valve are visible in Photo 33. Use caution while drilling the small hole through the entire length of the


5/16" dia.
3/16
5/16
No. 28 drill through
1/4" dia.
1/32" typ.
3/32" typ.
No. 32 drill through
4 places
2 9/16
1/8
13/16
13/32
1/8
1/8
1/8
5/8
13/64" dia.
1/4" dia.
1/8" dia. ream
.375" dia.
7/32" dia.
5/16" dia.
45° valve seat

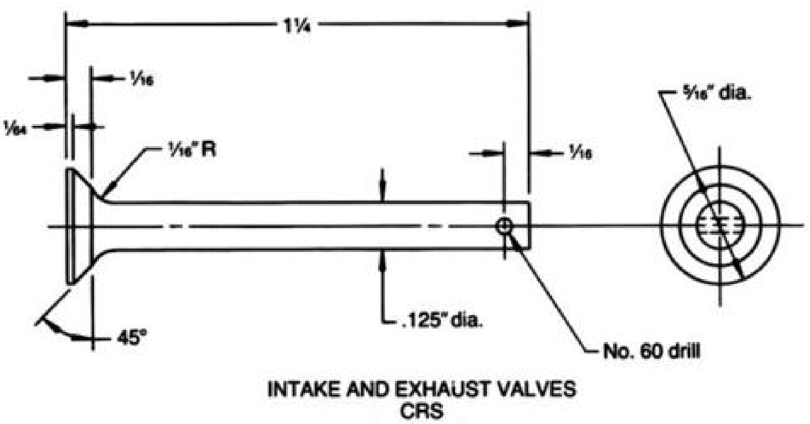
INTAKE VALVE BODY
CRS
1 required



32

jet body. Repeatedly back out the drill to clear the chips or it may break from excessive friction. Don't use cutting oil.

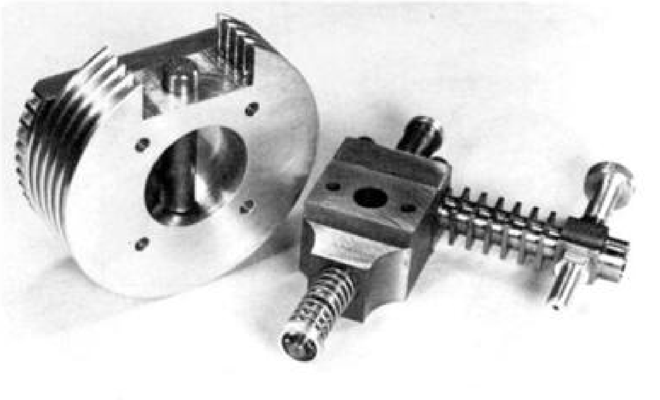
The completed Valve Units and Cylinder Head are displayed in Photo 34. The 1/4" rod visible in the cylinder head is merely there to help position the exhaust valve body while spot drilling the location for the two threaded bolt holes to be drilled into the flat recess. The actual machining of the cylinder head fins is in progress in Photo 35. If you lack aluminum cutting fluid, try regular sulfur base cutting oil; it works fine for me. The face end of the work should then be counterbored for the combustion chamber and the central hole through the head should be tapped for the spark plug threads. Cut off the head from the stock slightly longer than the finished size; then face off the top of the head and counterbore for the spark plug recess.



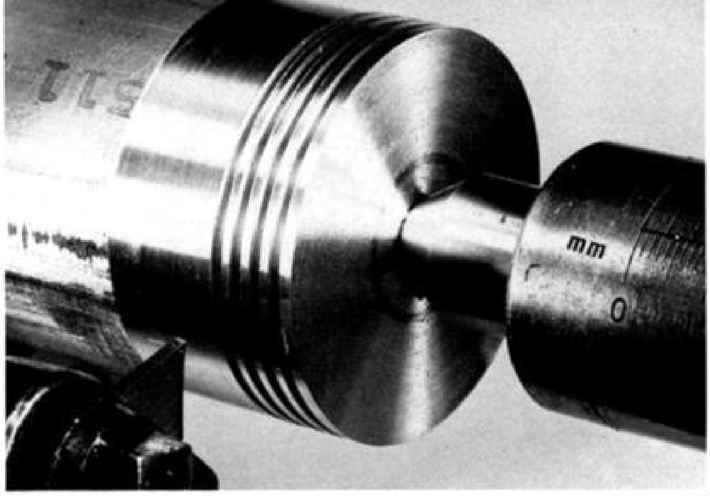
INTAKE AND EXHAUST VALVES
CRS
2 required

For precisely locating the four bolt holes through the head, use the milling machine (Photo 36). Center the rotary table to the mill spindle, and position the work true to the spindle. Now move the mill table the specified radius distance from the center for the bolt holes. Spot drill

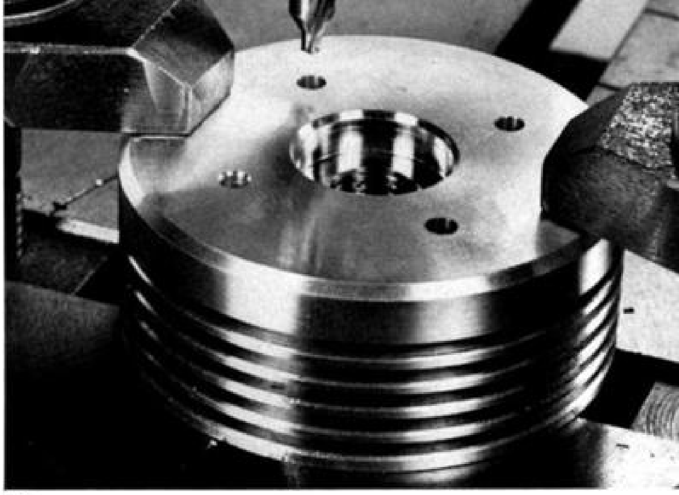
33



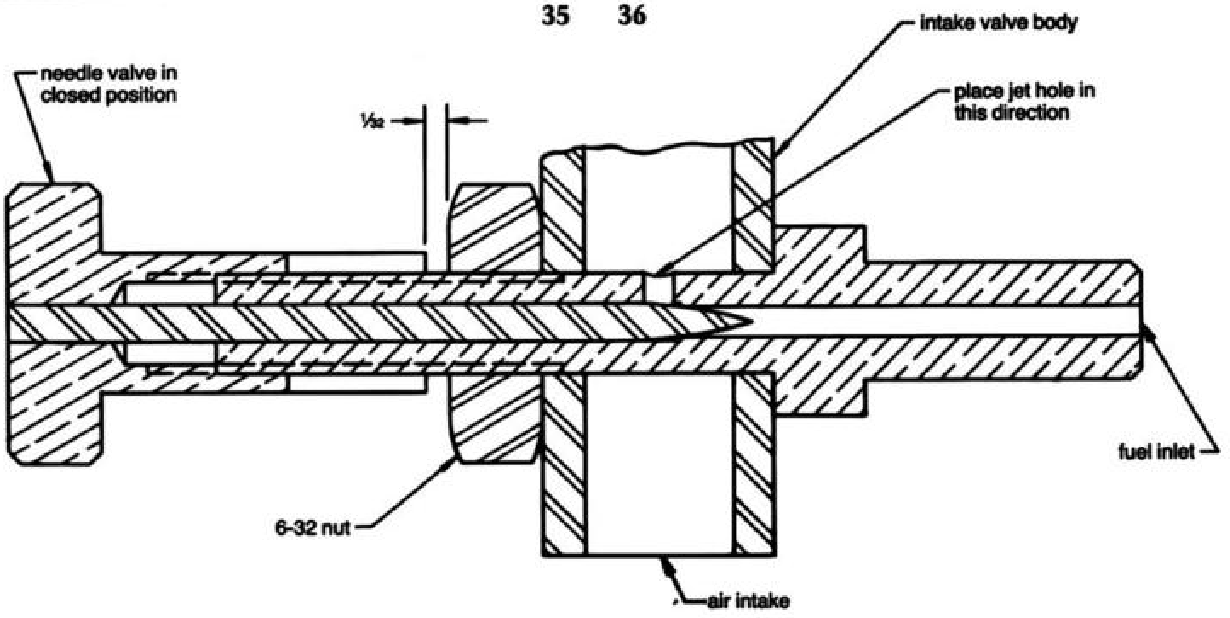
34



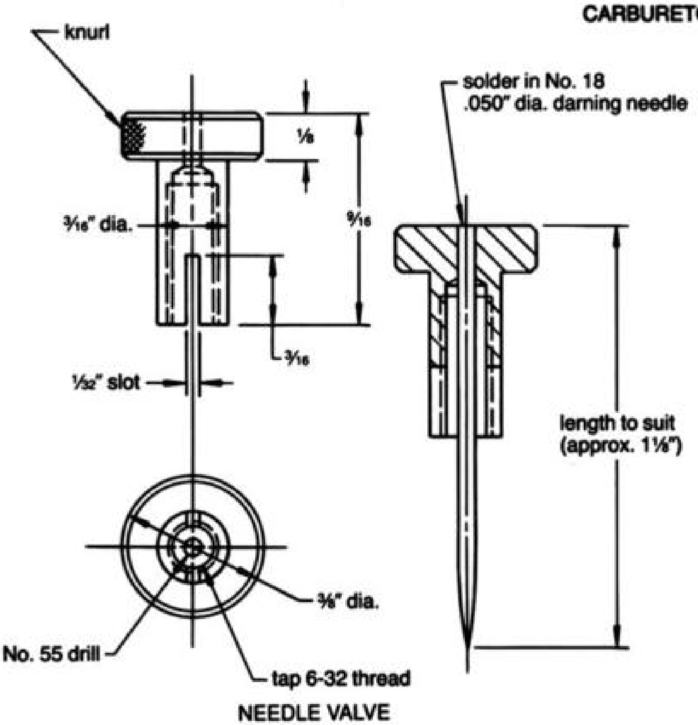
35



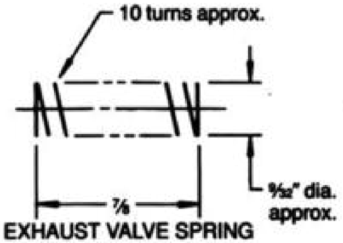
36


intake valve body
needle valve in closed position
place jet hole in this direction
1/32
fuel inlet
6-32 nut
air intake

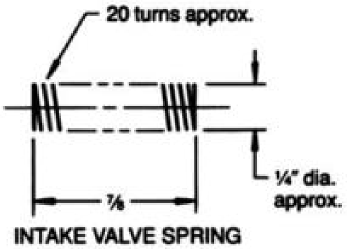
CARBURETOR ASSEMBLY


knurl
solder in No. 18 .050" dia. darning needle
1/8
3/16" dia.
9/16
3/16
1/32" slot
length to suit (approx. 1 1/8")
3/8" dia.
No. 55 drill
tap 6-32 thread

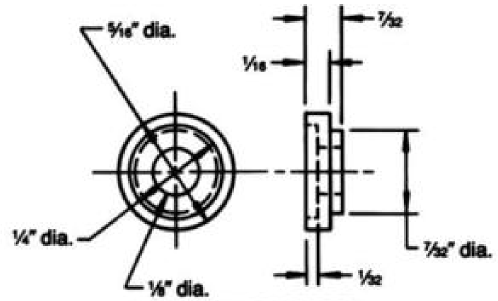
NEEDLE VALVE
brass
1 required


10 turns approx.
7/8
9/32" dia. approx.

EXHAUST VALVE SPRING
.022" dia. music wire
1 required


20 turns approx.
7/8
1/4" dia. approx.

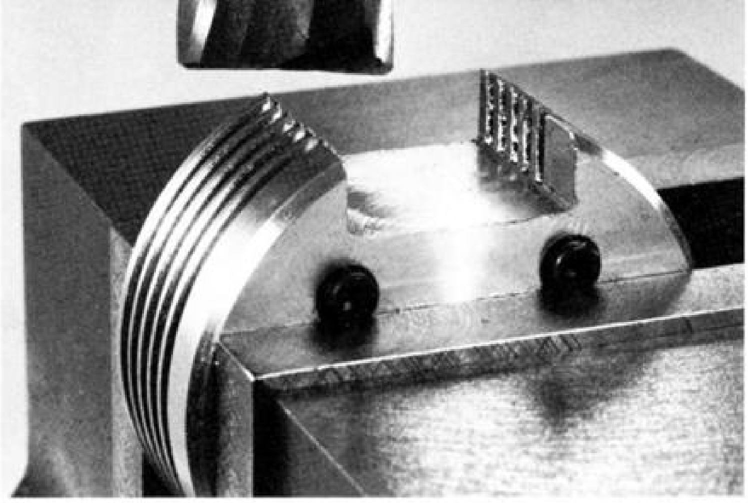
INTAKE VALVE SPRING
.013" dia. music wire
1 required


5/16" dia.
7/32
1/16
1/4" dia.
1/8" dia.
7/32" dia.
1/32

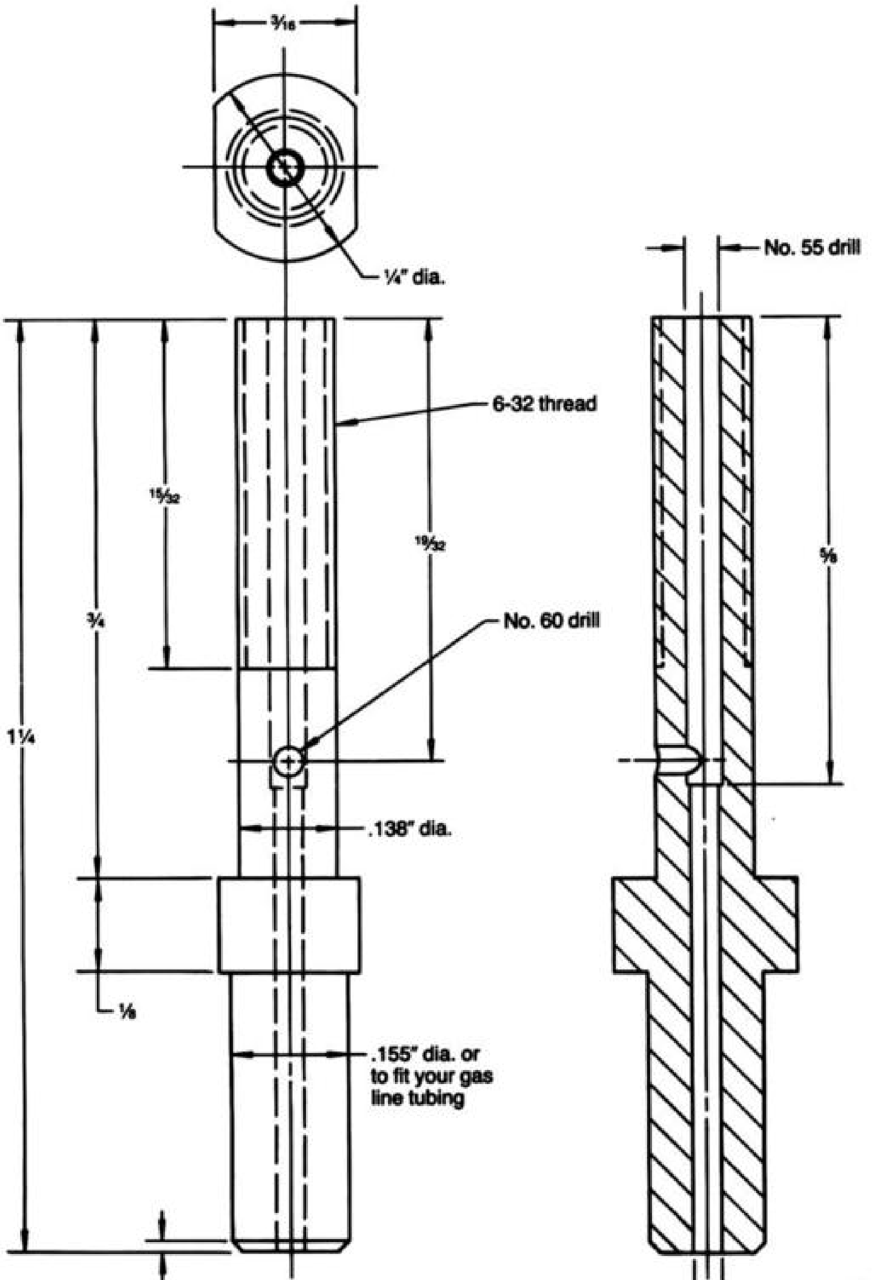
VALVE KEEPER
aluminum
2 required

the four locations 90° apart. The holes can then be drilled and counterbored in the drill press. The recess for the exhaust unit has been machined in Photo 37. Note the two bolt heads extended slightly to position the head parallel to the bolt holes. When milling the recess, lower the end mill gradually.

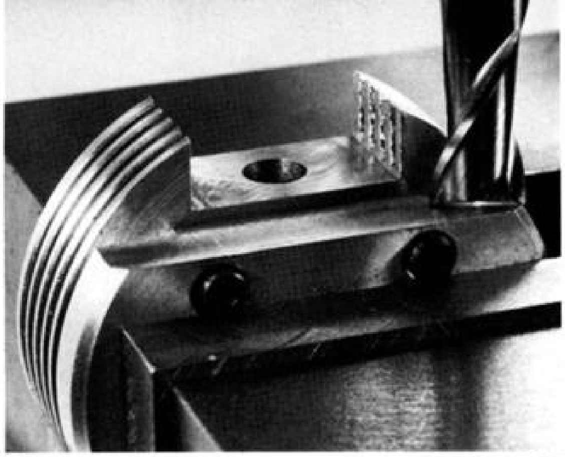
In Photo 38, the port hole into the combustion chamber has been drilled and the final step-cut taken to form one side of the first fin on the head. The remaining fins are machined, as in Photo 39. Begin forming the slots from the bottom upwards. Each slot is cut by one pass



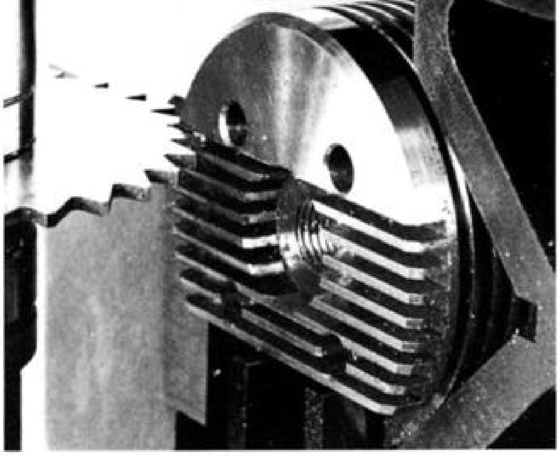
37


3/16
1/4" dia.
6-32 thread
15/32
19/32
3/4
1 1/4
No. 60 drill
.138" dia.
1/8
.155" dia. or to fit your gas line tubing
1/64" × 45°
No. 55 drill
5/8
No. 60 drill

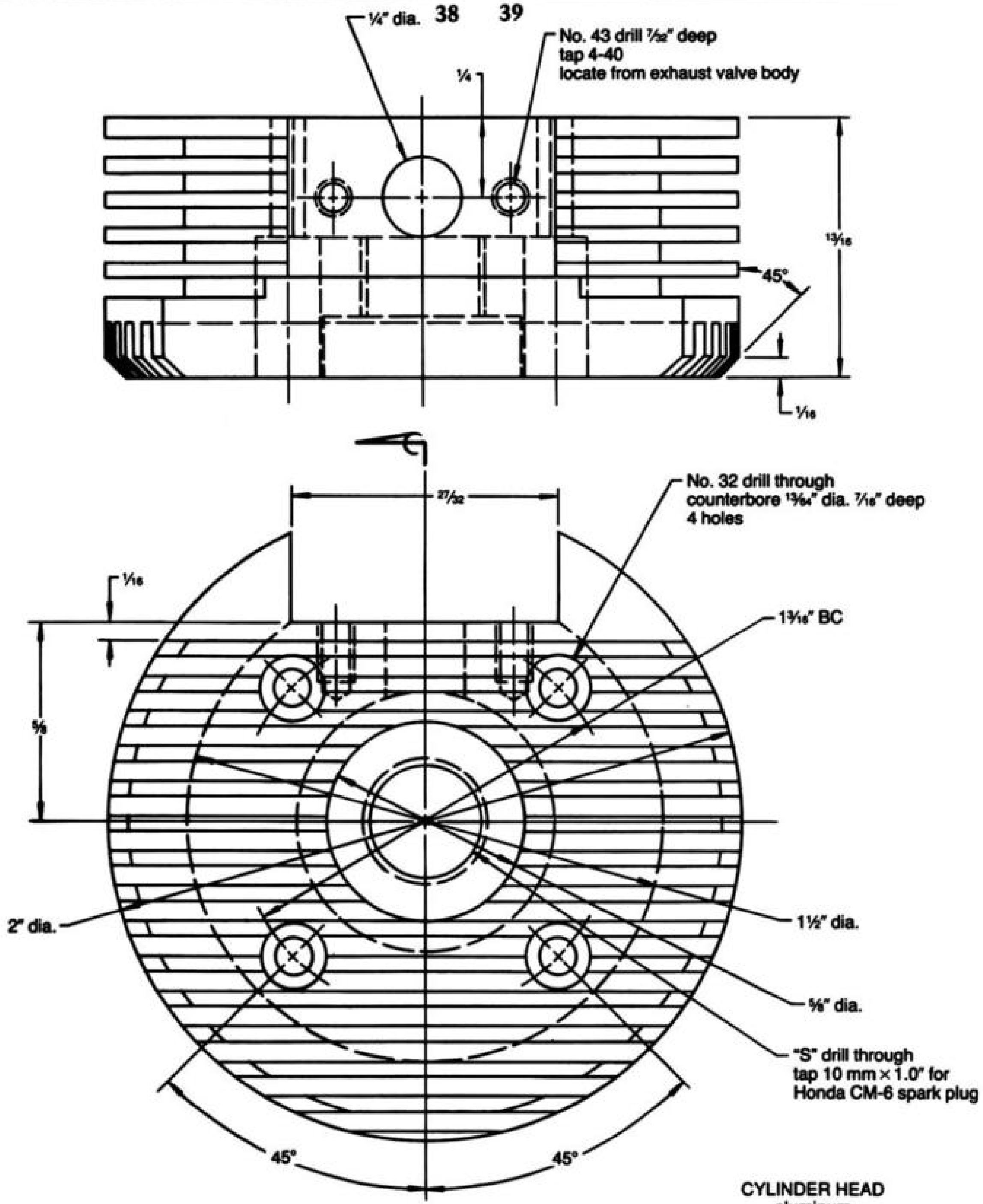
CARBURETOR JET
brass
1 required



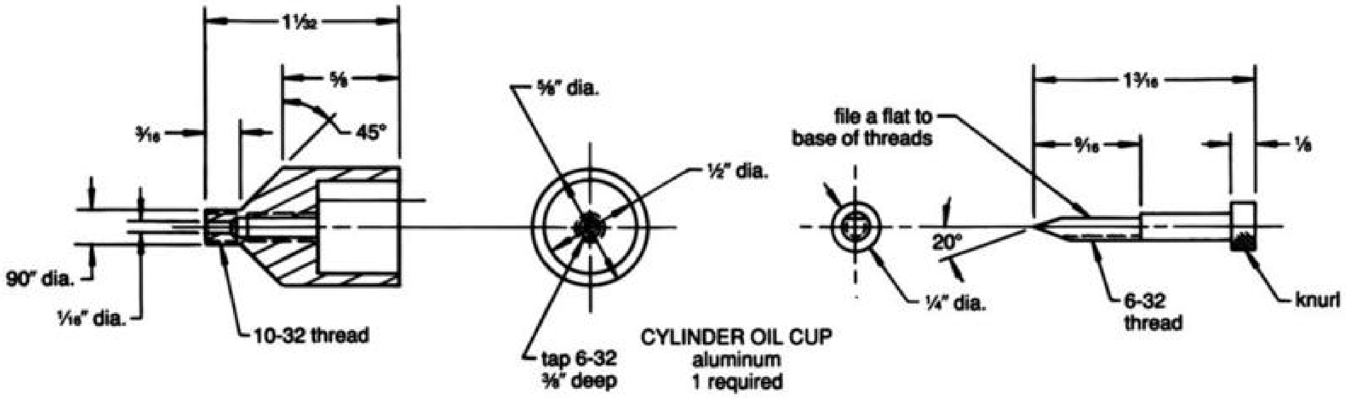
38



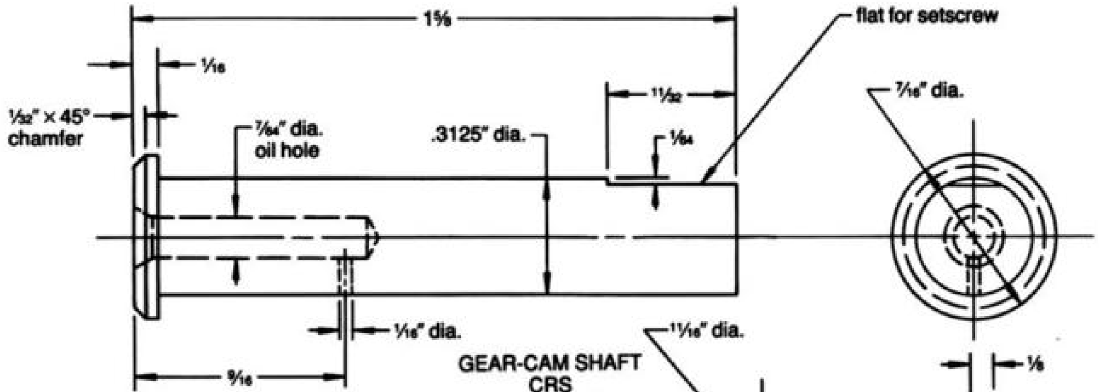
39


¼" dia.
No. 43 drill 7/32" deep
tap 4-40
locate from exhaust valve body
¼
13/16
45°
1/16
27/32
No. 32 drill through
counterbore 13/64" dia. 7/16" deep
4 holes
1/16
1 3/16" BC
⅝
2" dia.
1½" dia.
⅝" dia.
"S" drill through
tap 10 mm × 1.0" for
Honda CM-6 spark plug
45°
45°

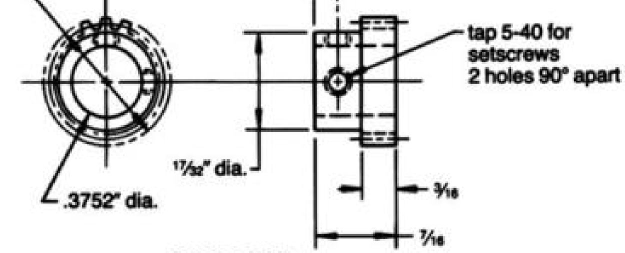
CYLINDER HEAD
aluminum
1 required


1 1/32
5/8
3/16
45°
90° dia.
1/16" dia.
10-32 thread
5/8" dia.
1/2" dia.
tap 6-32
3/8" deep
file a flat to
base of threads
1 3/16
9/16
1/8
20°
1/4" dia.
6-32
thread
knurl

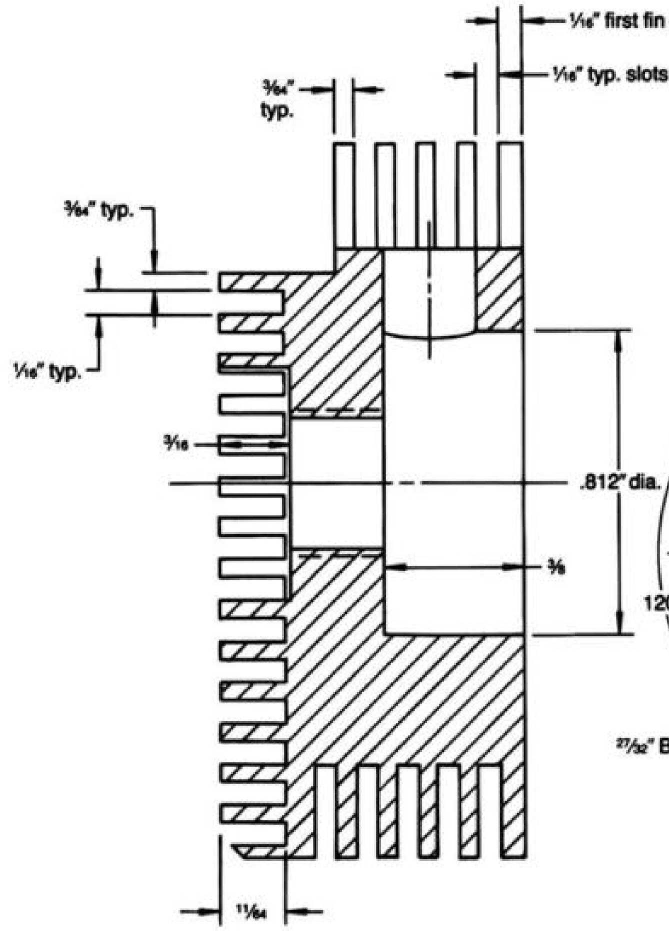
CYLINDER OIL CUP
aluminum
1 required

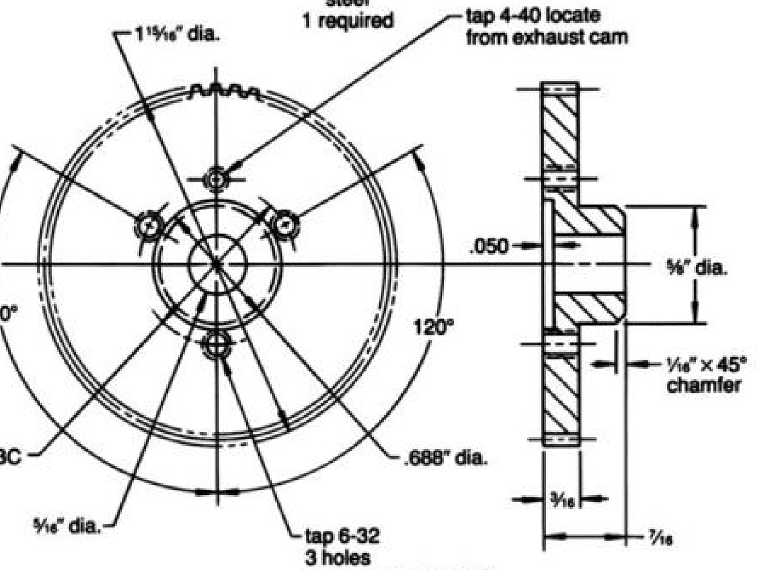

1 5/8
1/16
1/32" × 45°
chamfer
7/64" dia.
oil hole
.3125" dia.
11/32
1/64
flat for setscrew
7/16" dia.
1/16" dia.
9/16

GEAR-CAM SHAFT
CRS
1 required


11/16" dia.
1/8
tap 5-40 for
setscrews
2 holes 90° apart
17/32" dia.
.3752" dia.
3/16
7/16

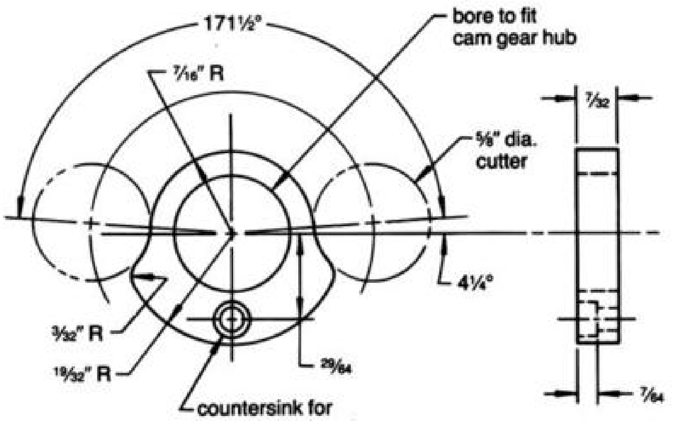
SPUR GEAR
32 pitch
20 teeth, pitch dia. .625"
steel
1 required


1/16" first fin only
1/16" typ. slots
3/64"
typ.
3/64" typ.
1/16" typ.
3/16
.812" dia.
3/8
11/64


1 15/16" dia.
tap 4-40 locate
from exhaust cam
120°
120°
.050
5/8" dia.
1/16" × 45°
chamfer
27/32" BC
.688" dia.
5/16" dia.
tap 6-32
3 holes
3/16
7/16

CAM GEAR
spur gear, 32 pitch
60 teeth, pitch dia. 1.875"
brass
1 required

of the 1/16" slitting saw; be certain that the depth of the cut is slightly above the spark plug seat; we don't want slits in that! Also use a slow gentle feed while cutting so as not to dislodge the workpiece.

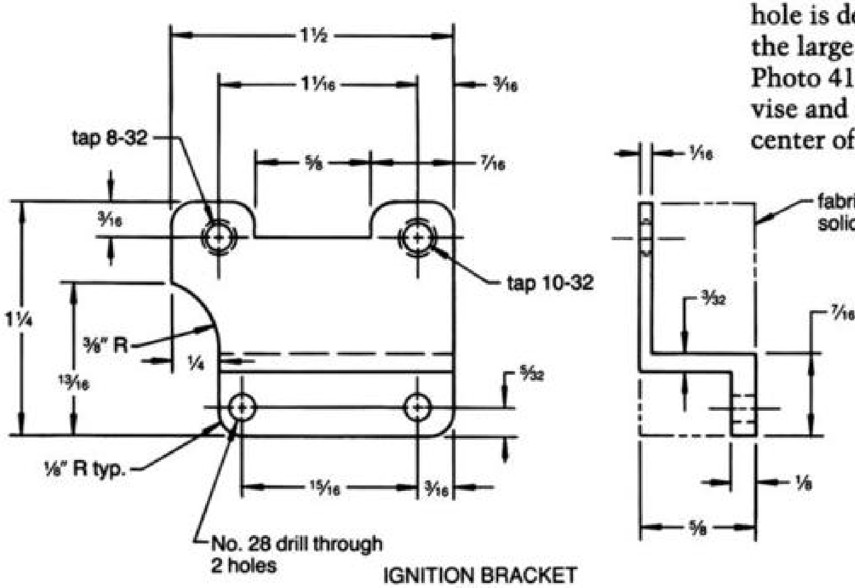

171½°
bore to fit cam gear hub
7/16" R
7/32
5/8" dia. cutter
4¼°
3/32" R
19/32" R
29/64
7/64
countersink for 4-40 socket head cap screw

EXHAUST CAM
CRS
1 required

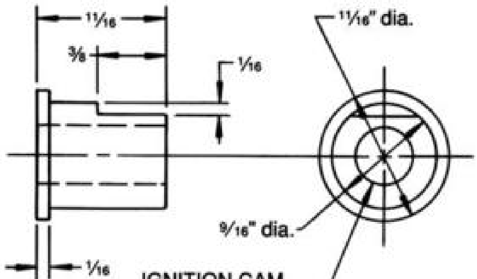
Photo 40 shows the head in the proper position for spot drilling the location of the four threaded holes in the cylinder flange. Put the engine on a surface plate, and place the blade of a square against the side of the first vertical fin on the head. Employ two parallel clamps to hold the head securely to the cylinder. Remove the cylinder from the body and spot drill through the head.

The Timing Gears and Cams are next. The small steel gear must be bored to 3/8" ID. Chuck it in a four-jaw chuck on the hub portion of the gear. Dial indicate the bore for a zero reading. Also check the outer face for wobble. Then drill the hole to 23/64" and bore to 3/8" for a snug fit on the crankshaft. Two setscrews and two shallow flats formed on the shaft to take the pressure from the screws will hold the gear firmly in place. The hub side of the gear is positioned next to the engine body.

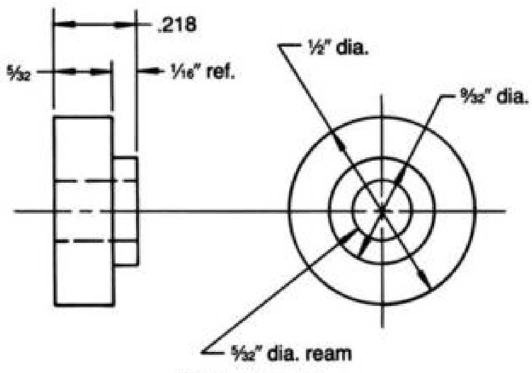
The Exhaust Cam blank is left attached to its stock piece for machining. The bore of the cam hole is determined by the actual diameter of the large gear hub; make it a snug slip fit. In Photo 41, the cam blank is clamped in a small vise and the work centered up true to the center of the rotary table. Use a 5/8" end mill


1½
1 1/16
3/16
tap 8-32
5/8
7/16
3/16
tap 10-32
1¼
3/8" R
1/4
13/16
5/32
1/8" R typ.
15/16
3/16
No. 28 drill through
2 holes
1/16
fabricate from solid block
3/32
7/16
1/8
5/8

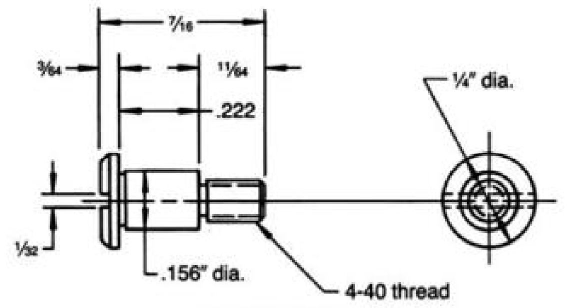
IGNITION BRACKET
CRS
1 required


11/16
3/8
1/16
11/16" dia.
9/16" dia.
1/16
5/16" dia. ream

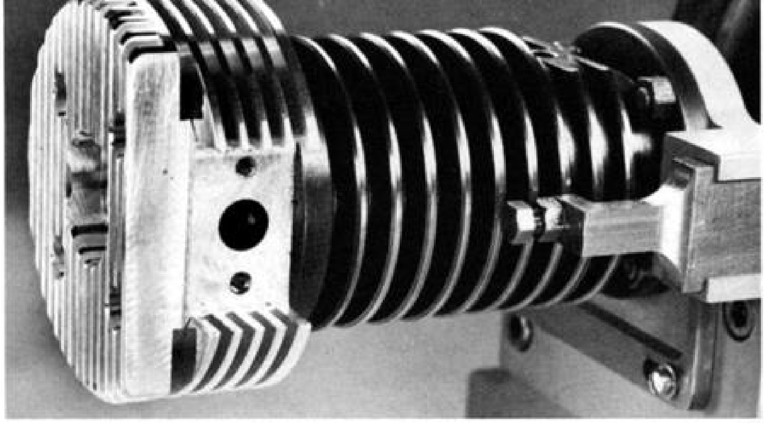
IGNITION CAM
CRS
1 required


.218
5/32
1/16" ref.
1/2" dia.
9/32" dia.
5/32" dia. ream

CAM ROLLER
CRS
1 required

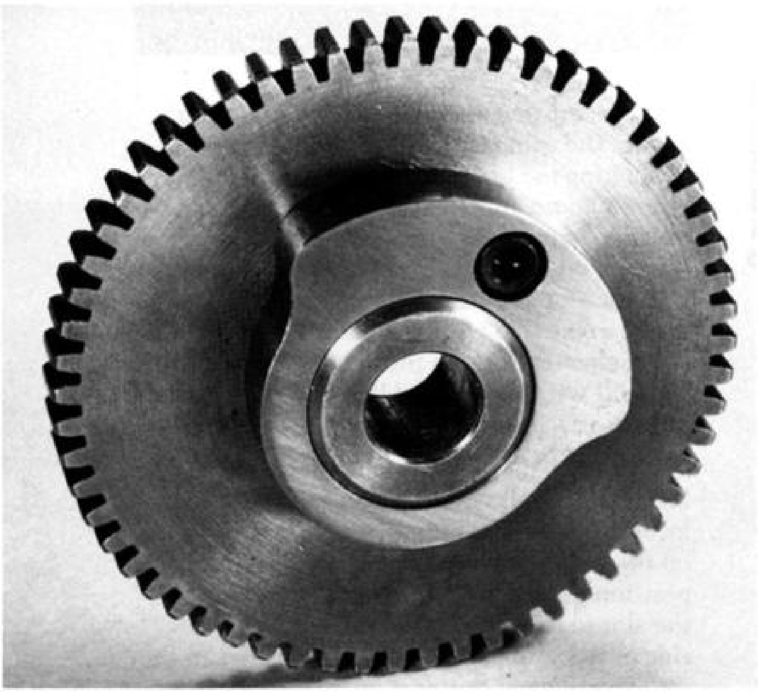

7/16
3/64
11/64
.222
1/4" dia.
1/32
.156" dia.
4-40 thread

CAM ROLLER BOLT
CRS
1 required
case harden for best results
(optional)

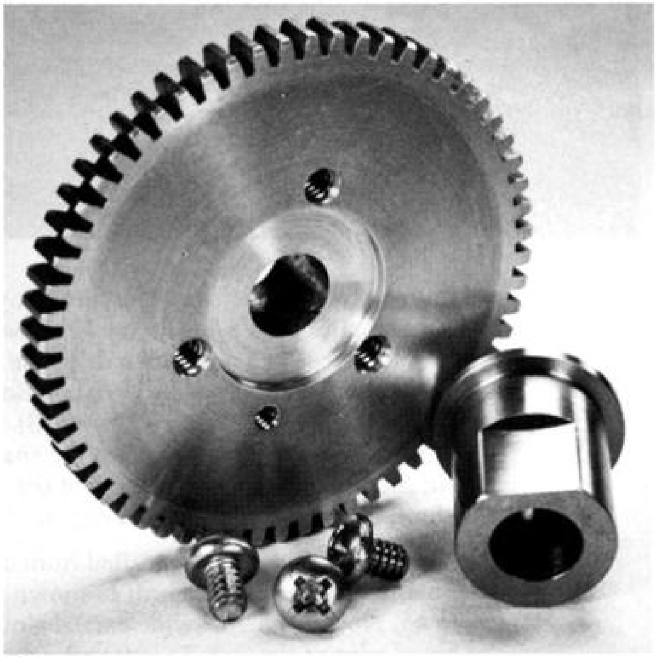


40

41

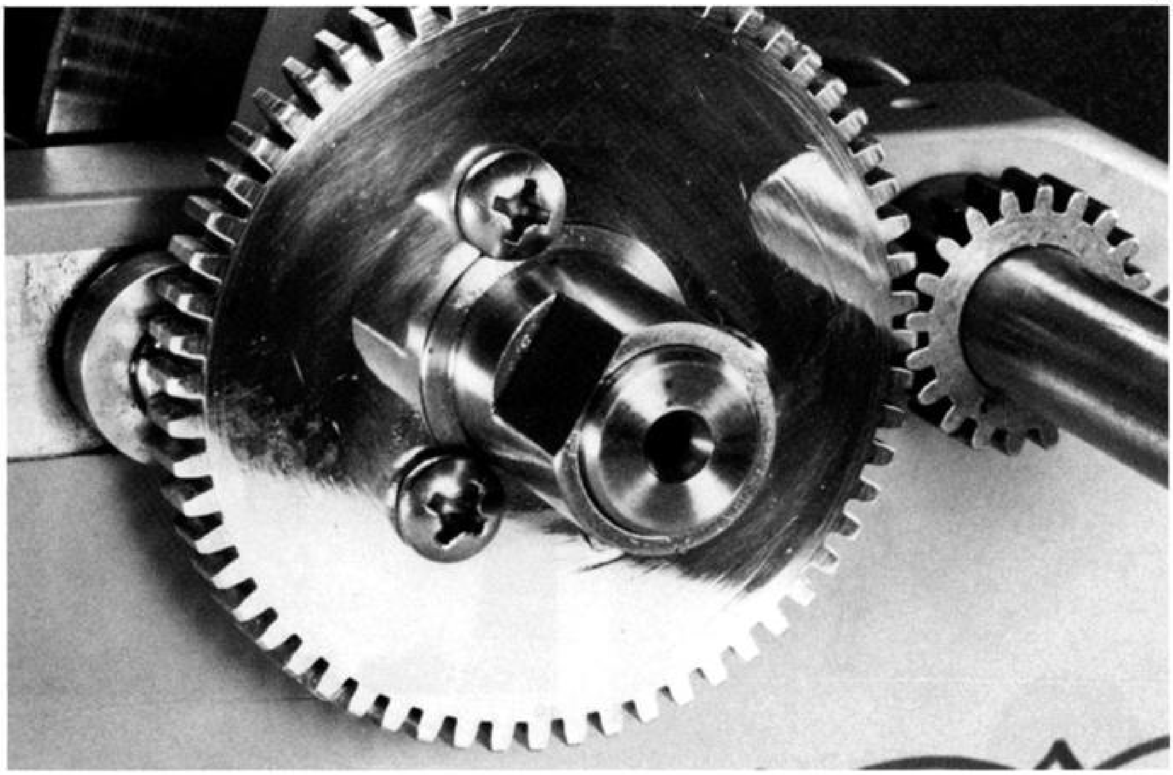


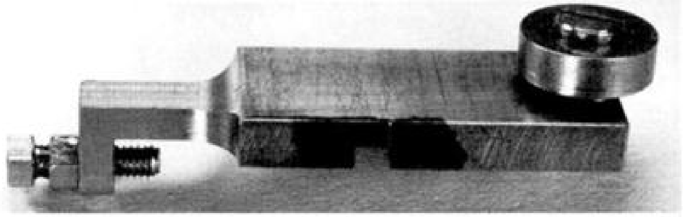
42



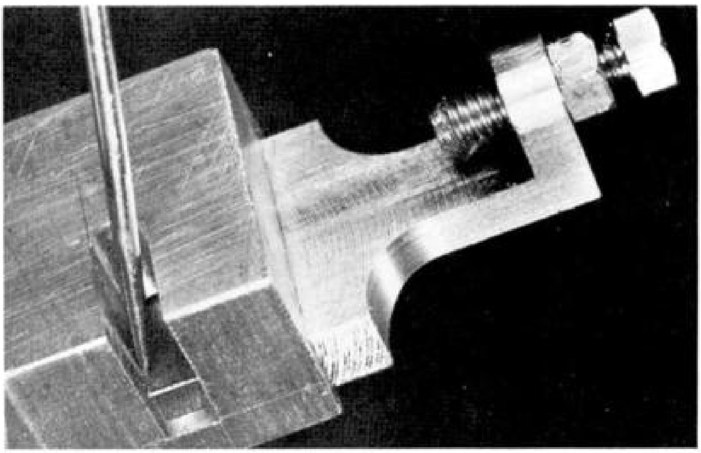
43

44

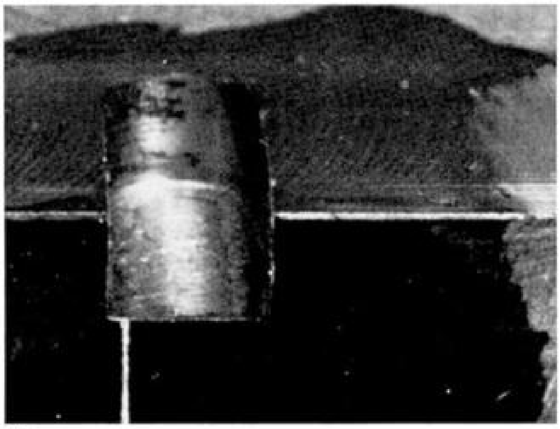




45



46

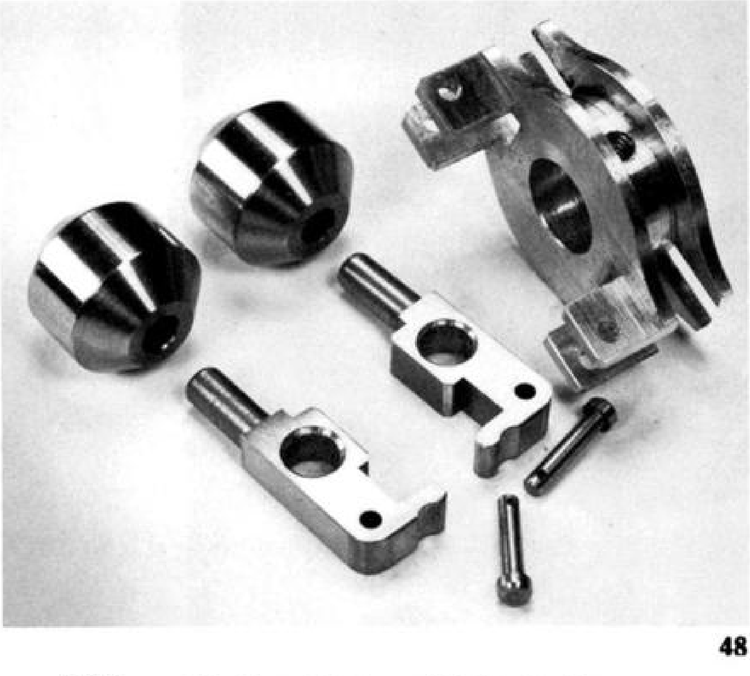


47

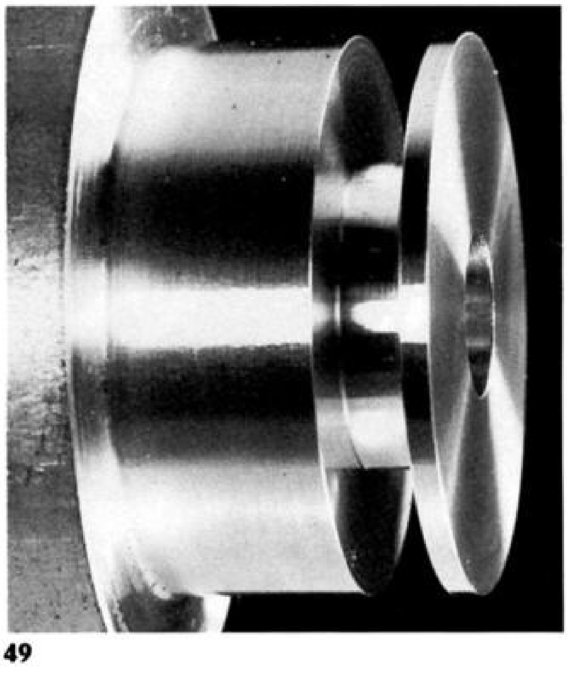
to form the step on the cam. Don't employ an end mill smaller than 5/8". Photo 42 shows the cam in place. The opposite side of the gear is machined for a shallow recess to position the flange of the Ignition Cam (Photo 43). The recess should be absolutely true to the shaft hole in the gear. Photo 44 is a view of the camshaft, the gears, and ignition cam in place.

The Cam Push Rod is easily milled from a steel blank. The completed unit is shown in Photo 45. Notice the 1/8" wide partial slot, in the blued edge of the rod. To locate the proper position in which to mill this slot, the exhaust cam and gear must be in place on the engine body. Insert the push rod into its guide slot. Rotate the cam gear so the Cam Roller is contacting the highest portion of the cam. Now refer to Photo 46, a closeup of the slot you have previously milled through the body frame and into the push rod guideway. Apply layout blue into the slot and onto the push rod. When dry, scribe a fine line with a needle along the slot side indicated. Clamp the valve push rod in the mill with the scribed line exposed on the upper surface.

In Photo 47, the vertical white line on the lower edge of the push rod represents the location of the fine line that was just scribed on the side of the push rod. The idea is to position the 1/8" end mill so the left side of the slot to be milled will be .010" to the left side of the scribed line. Install a wiggler in the mill spindle and center it over the line. Now set the table travel calibrated collar to zero.



48



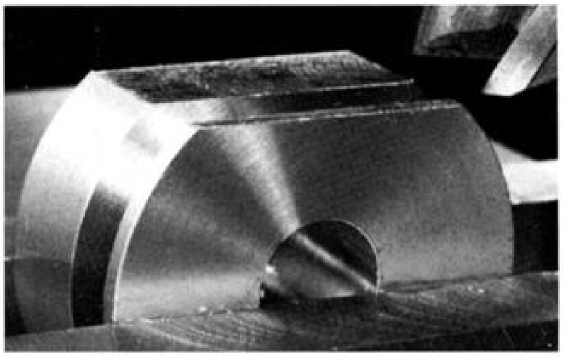
49

Install a 1/8" end mill, move the table to the left .052", and lock it. This will place the cutter in the proper position for milling the slot. Check to make certain, then gradually mill down to form the cavity.

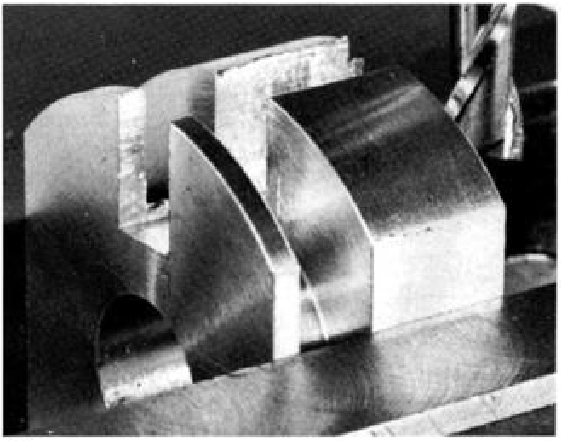
Parts of the main governor unit are shown in Photo 48. Start with the Governor Bracket and machine, as in Photo 49. Part it from the stock, leaving it a little thick for facing off the unfinished end. Then mount it in the mill vise and mill a flat on the perimeter to the proper depth (Photo 50).

Reinsert the work in the vise with the surface just milled downward and seated on a parallel. Again, mill a flat equal in depth to the first one. Now position the work, as in Photo 51. Center up the mill spindle and cut the vertical slot; do likewise on the opposite side of the piece. Then place the work on an adjustable parallel in the vise so the sections to be milled are barely exposed above the jaws (Photo 52). Note the thin cardboard between the work and the movable jaw to establish a firm grip.

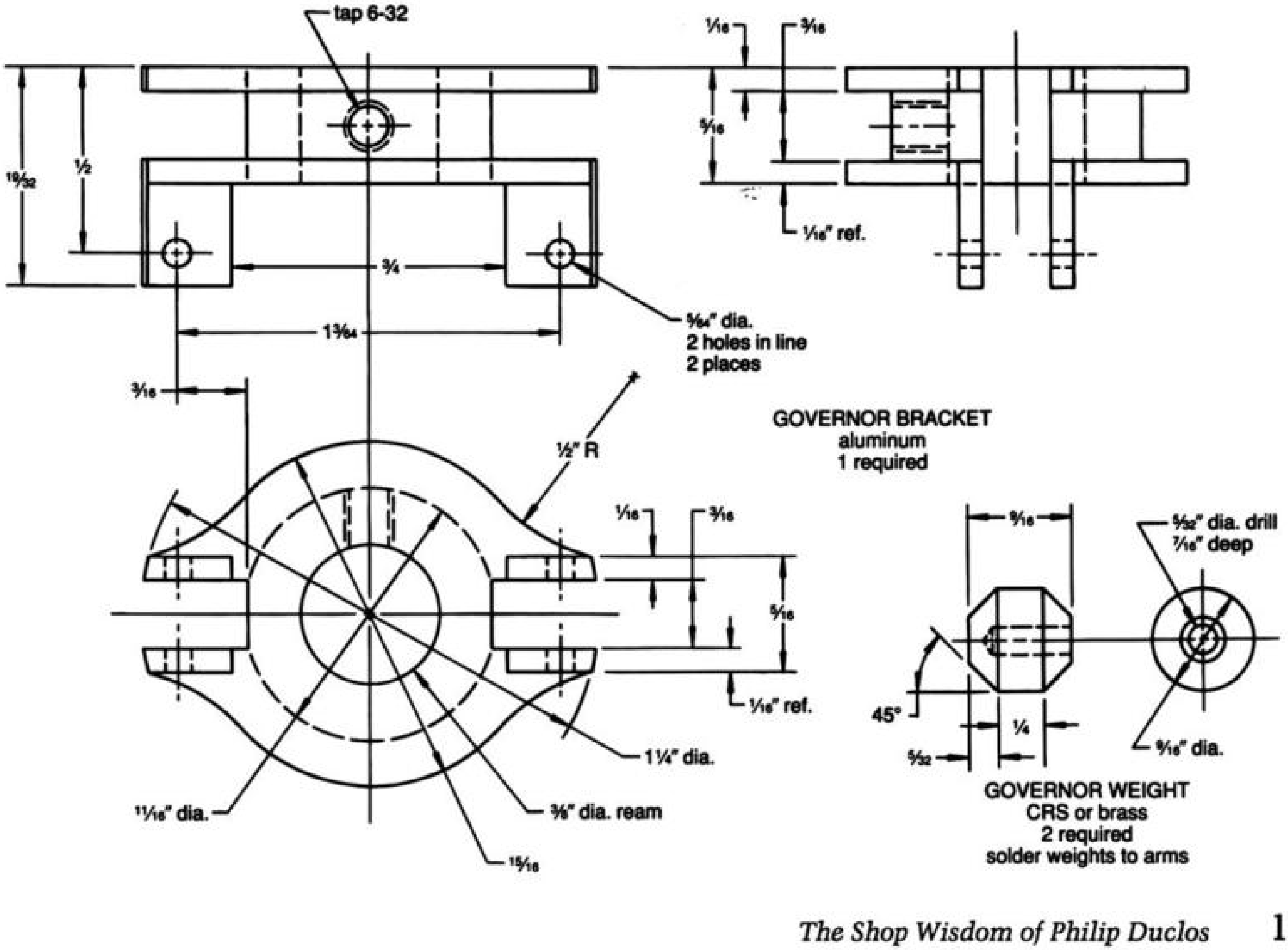
Without changing the setup, mill across the work to form the four bracket ears (Photo 53). If you wish to contour the outer rims of the bracket (optional) see Photo 54. Clamp the

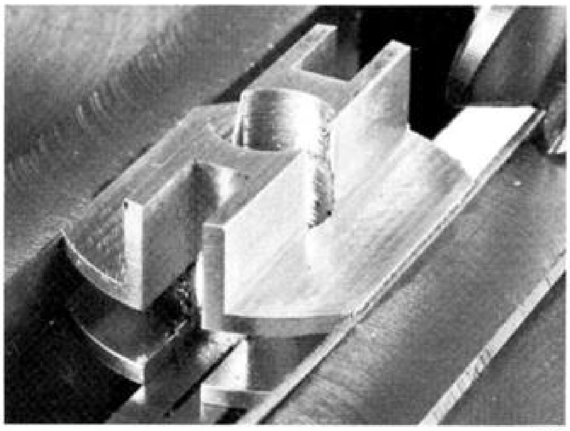


50

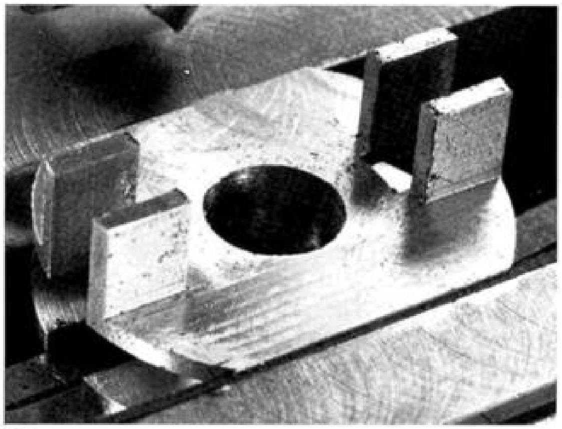


51


tap 6-32
19/32
1/2
3/4
1 3/64
3/16
1/16
3/16
5/16
1/16" ref.
5/64" dia.
2 holes in line
2 places
GOVERNOR BRACKET
aluminum
1 required
1/2" R
1/16
3/16
5/16
1/16" ref.
1 1/4" dia.
11/16" dia.
3/8" dia. ream
15/16
9/16
5/32" dia. drill
7/16" deep
45°
1/4
5/32
9/16" dia.
GOVERNOR WEIGHT
CRS or brass
2 required
solder weights to arms



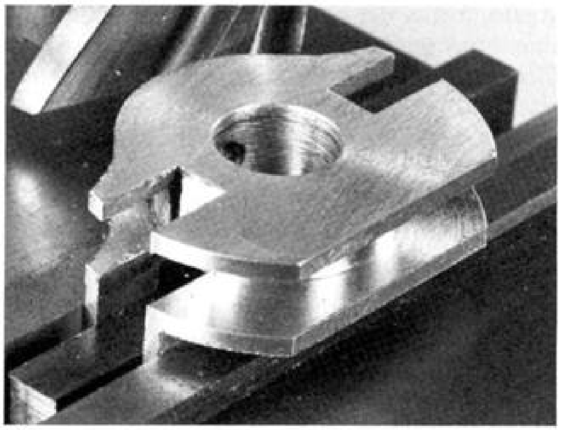
52



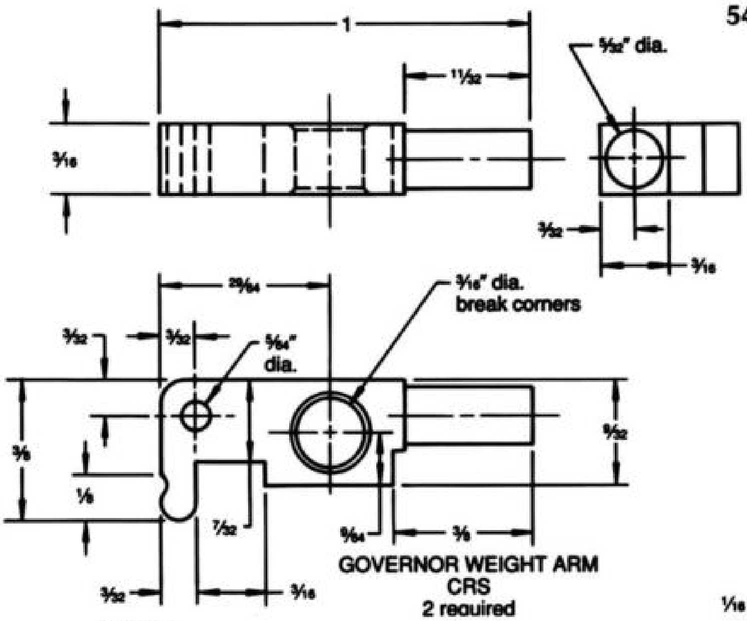
53

work in a small vise; note the piece of square rod inserted between the bracket ears. Position the vise on the rotary table and center the workpiece true to the rotary table center point. Mill the contour with a 1" end mill.

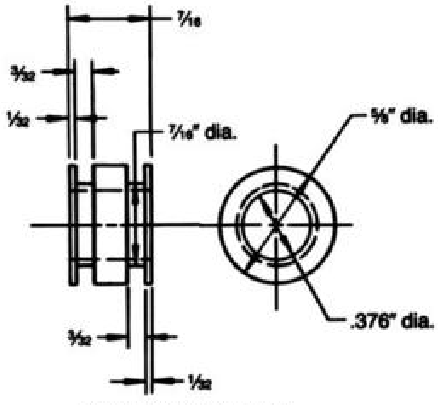
Lay out the blanks for the two Governor Weight Arms. Clamp the two blanks together evenly and drill the two cross holes through both pieces. Some excess material can be removed by step-cutting the blank in the mill on the ends where the round shaft section will be turned. A portion of the remaining step-cut is visible in Photo 55.



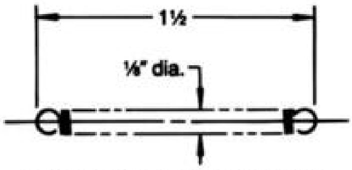
54


1
11/32
5/32" dia.
3/16
3/32
3/16
29/64
3/16" dia.
break corners
3/32
3/32
5/64"
dia.
3/8
1/8
9/32
7/32
9/64
3/8
3/32
3/16
free fit in
slot on governor
sleeve

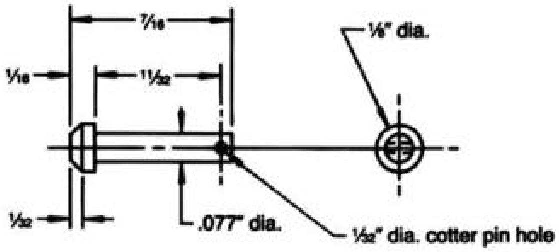
GOVERNOR WEIGHT ARM
CRS
2 required


7/16
3/32
1/32
7/16" dia.
5/8" dia.
.376" dia.
3/32
1/32

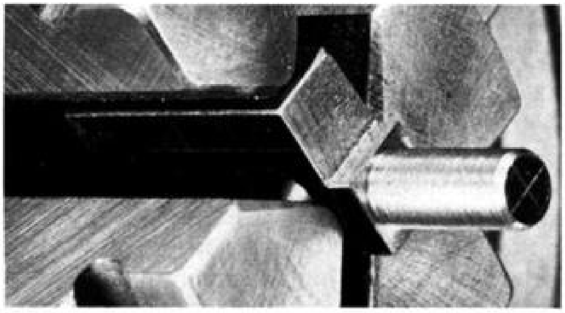
GOVERNOR SLEEVE
CRS
1 required



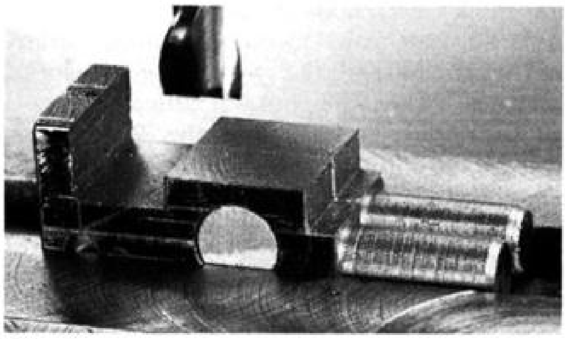
GOVERNOR TENSION SPRING
.013" dia. music wire
approx. 96 turns
1 required


7/16
1/8" dia.
1/16
11/32
1/32
.077" dia.
1/32" dia. cotter pin hole

GOVERNOR ARM PIVOT PIN
CRS
2 required

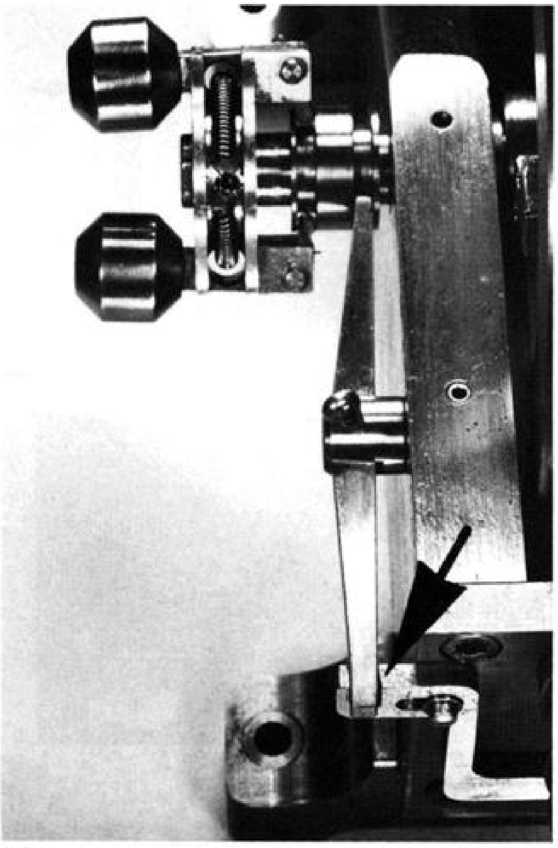


55

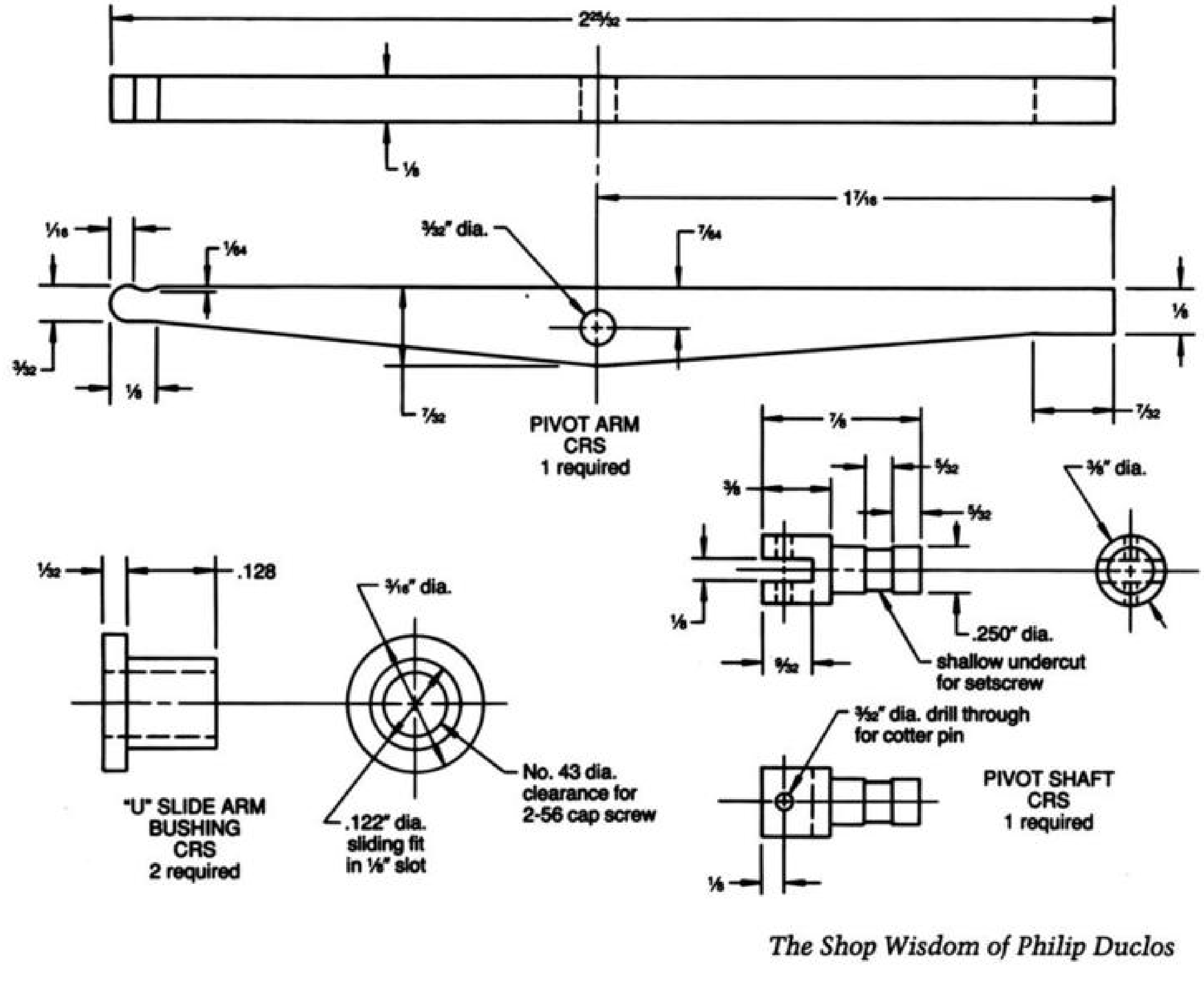


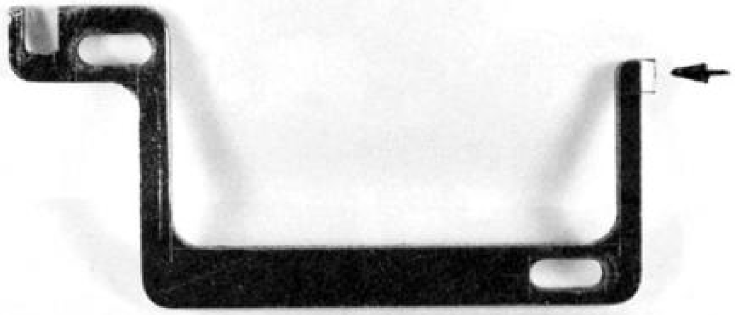
56

When the shaft ends are completed, clamp the two arms together with short pieces of rod through both holes; mill out the remaining contours (Photo 56). Carefully mill or file the proper curve on the "finger" tip of each arm to

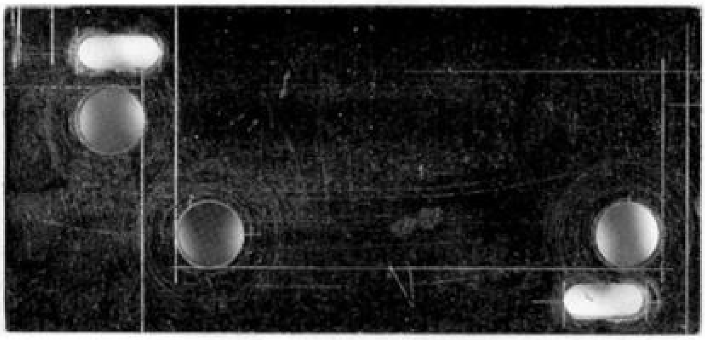


57

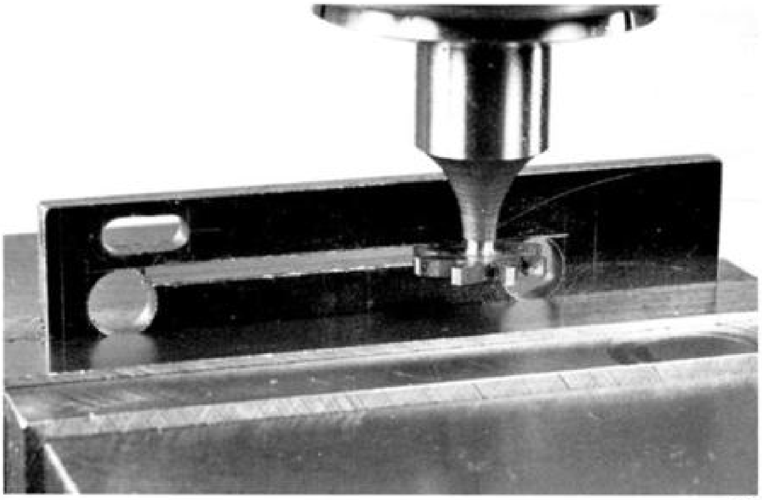

2 25/32
1/8
1/16
1/64
3/32" dia.
7/64
1 7/16
1/8
3/32
1/8
7/32
7/32
PIVOT ARM
CRS
1 required
7/8
5/32
3/8
5/32
3/8" dia.
1/8
9/32
.250" dia.
shallow undercut
for setscrew
3/32" dia. drill through
for cotter pin
PIVOT SHAFT
CRS
1 required
1/8
1/32
.128
3/16" dia.
"U" SLIDE ARM
BUSHING
CRS
2 required
.122" dia.
sliding fit
in 1/8" slot
No. 43 dia.
clearance for
2-56 cap screw



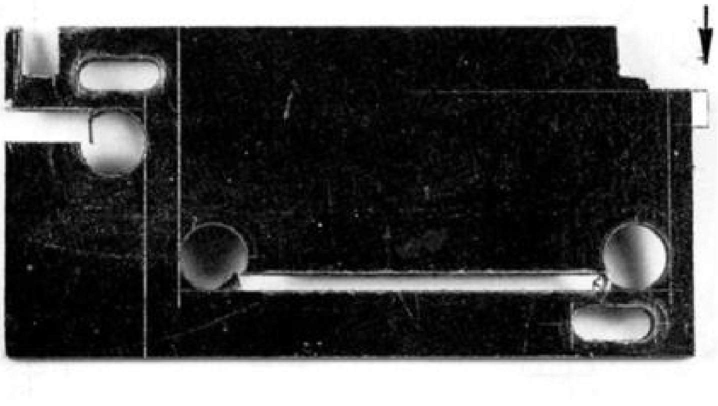
58



59



60



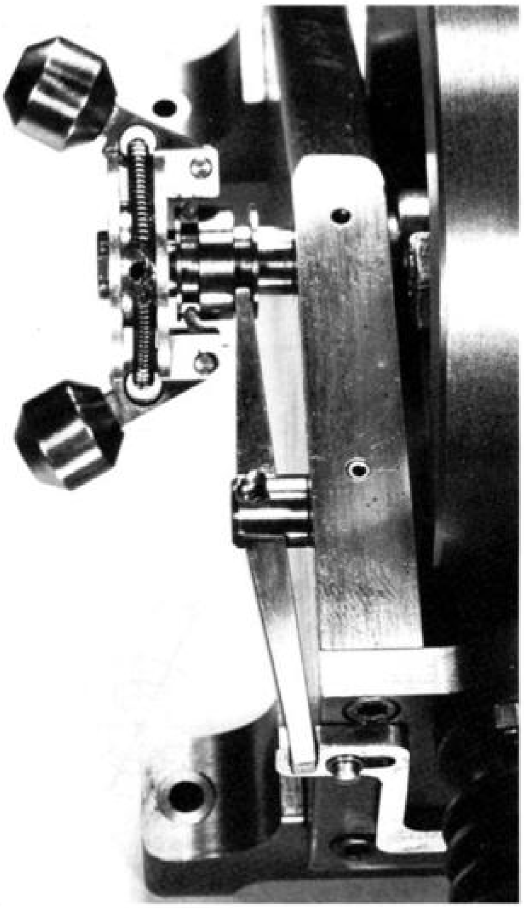
61

prevent binding in the governor spool slot. Finally, solder the weights in place on each arm.

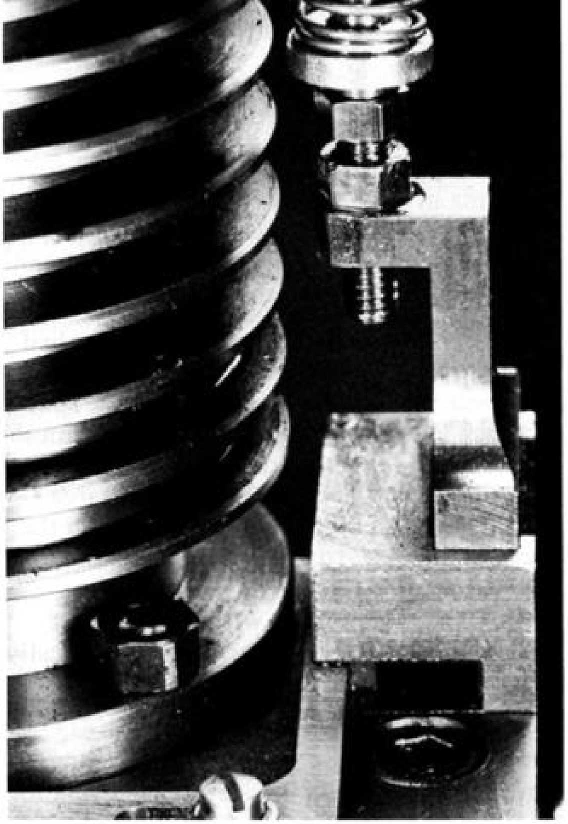
Make and assemble the Pivot Arm and Pivot Shaft. The long pivot arm is visible in Photo 57. This arm transfers the motion from the Governor Spool to the "U" Slide Arm situated on the engine body backplate. Note the 6° slant in the notch in the "U" slide arm to prevent the pivot arm from binding when in motion.

The "U" slide arm is cut from a flat piece of 1/8" thick CRS (Photo 58). Observe the all important catch tip. Lay out the configuration for the arm and mill the two short guide slots, followed by the radius holes (Photo 59). Now cut a slit between the radius holes (Photo 60). Mill off one end of the plate to form the catch pin (Photo 61). Remove the remaining excess material with a hacksaw and smooth up to complete the piece.

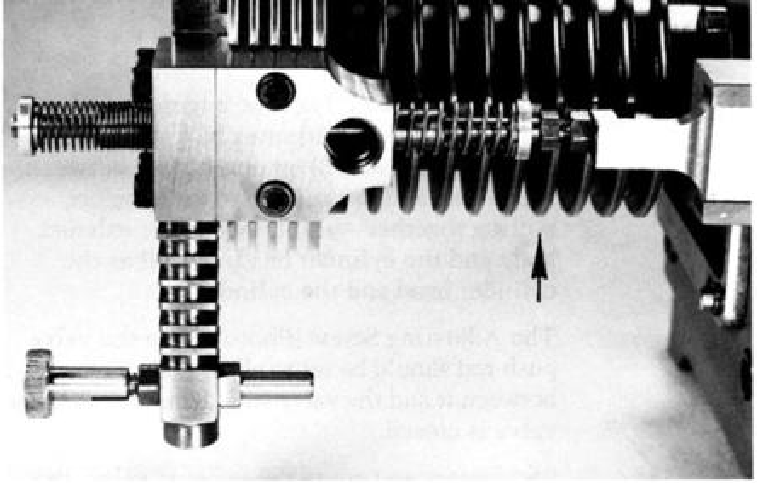
The purpose of the slide arm is to transfer the governor motion over to the cam push rod. Refer back to Photo 57. When the motor is stopped or running slowly, everything will be in this position. As the RPM increases, the governor assembly will fly out to this position (Photo 62).



62

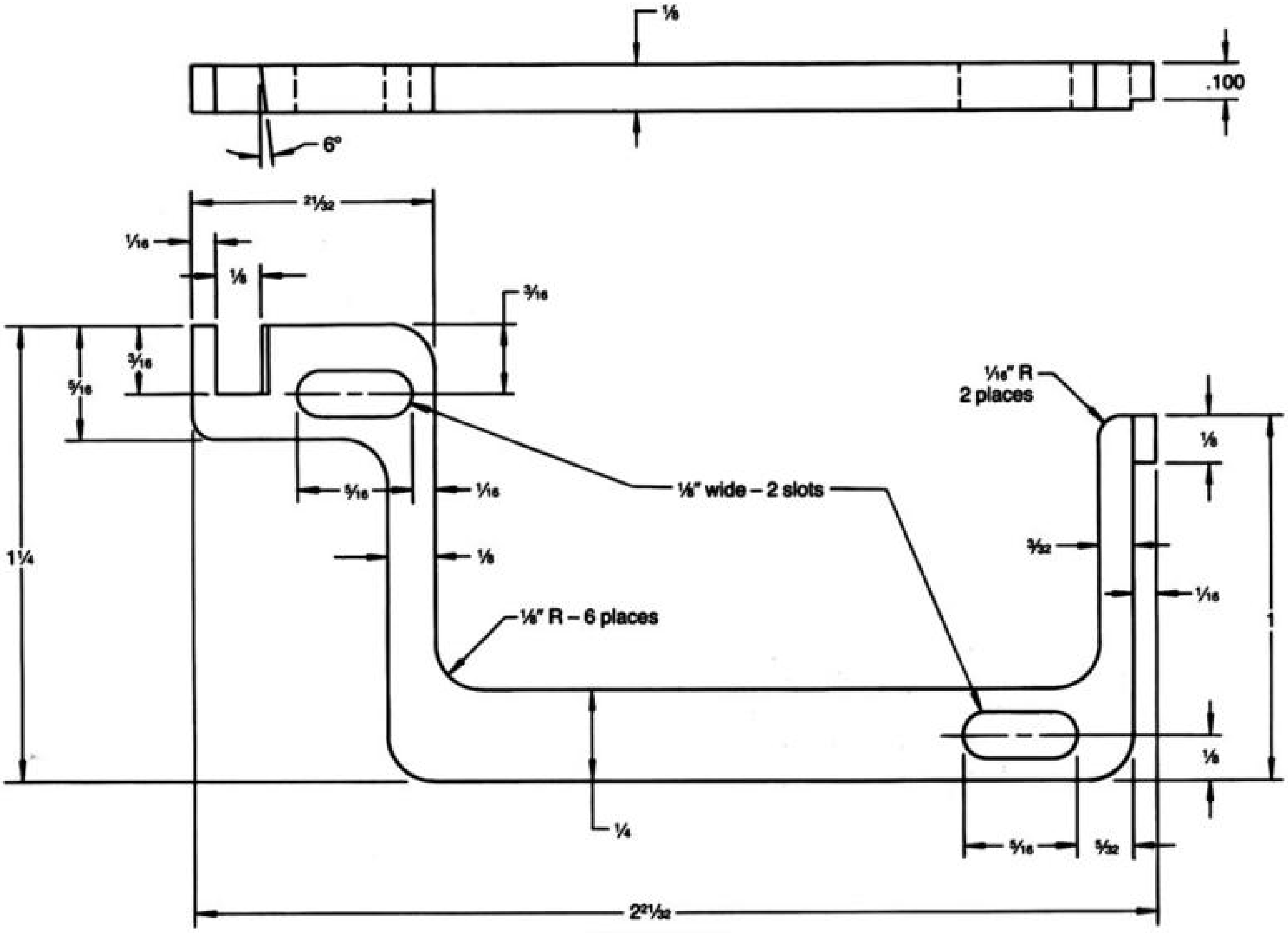


63



64

A clear view of the opposite end of the slide arm is visible in Photo 63. This picture was taken below the engine looking upwards. Note a portion of the catch tip visible in the slot. In this position, the governor is inactive. When the governor is in motion, the slide arm moves to the right and its catch pin tip will engage in the 1/8" slot in the cam push rod, thus holding the exhaust valve open until the motor slows down.



1/8
.100
6°
21/32
1/16
1/8
3/16
3/16
5/16
1/16" R
2 places
1/8
5/16
1/16
1/8" wide – 2 slots
1 1/4
1/8
3/32
1/16
1/8" R – 6 places
1
1/8
1/4
5/16
5/32
2 21/32

"U" SLIDE ARM
CRS
1 required

Upon final assembly of the engine, smear a very thin layer of Permatex Silicone *Form-A-Gasket* (Part No. 6B) on one surface between the intake and exhaust valve units before bolting together – also between the exhaust body and the cylinder head, as well as the cylinder head and the cylinder.

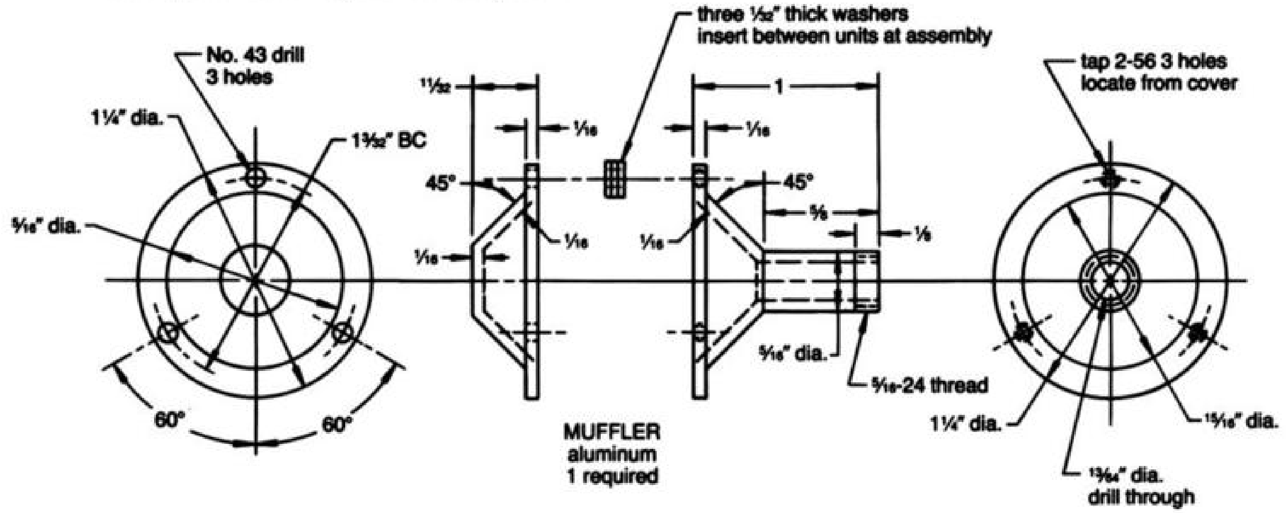
The Adjusting Screw (Photo 64) on the valve push rod should be set to allow a .006" clearance between it and the valve stem when the exhaust valve is closed.

Preparatory to timing the exhaust valve, the small gear must be secured to the main shaft. Tighten the two screws in the gear hub until they firmly press against the indentations you have made for them on the shaft. Now the cam gear is the one to adjust. Refer back to Photo 44. The cam gear is mounted in place, but do not tighten the setscrew that locks the camshaft rod in place.

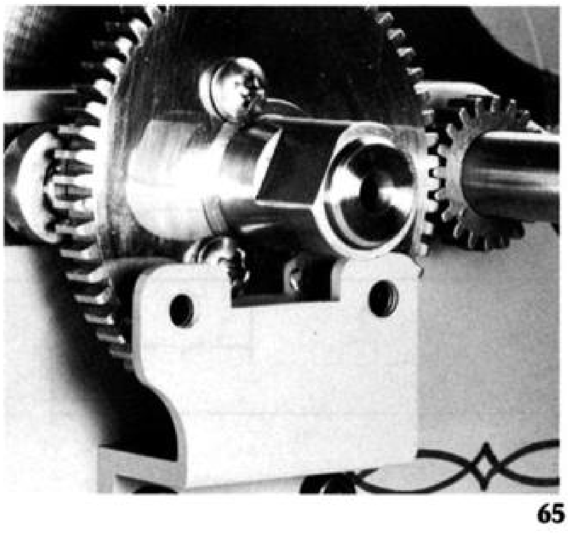
Turn the flywheel in a clockwise direction until the piston is at the end of its inward stroke (towards the cylinder head). Now slowly pull the cam gear and its shaft outward just enough to disengage it from the small gear. Remember that the large gear will be revolving in a counterclockwise direction. Now turn the freed cam gear counterclockwise and observe the valve push rod cam roller and also the high portion of the cam.

In theory, when the cam roller has just rolled off the high portion of the cam and touches the lower section of the cam, that is the spot in which to push the large gear back into mesh with the little gear; in other words, with the piston at top dead center the exhaust valve should have just closed completely. Mesh the two gears as close to this setting as possible, then tighten the setscrew to secure the camshaft. Don't worry about when the exhaust valve will open; the cam lobe will automatically take care of that.

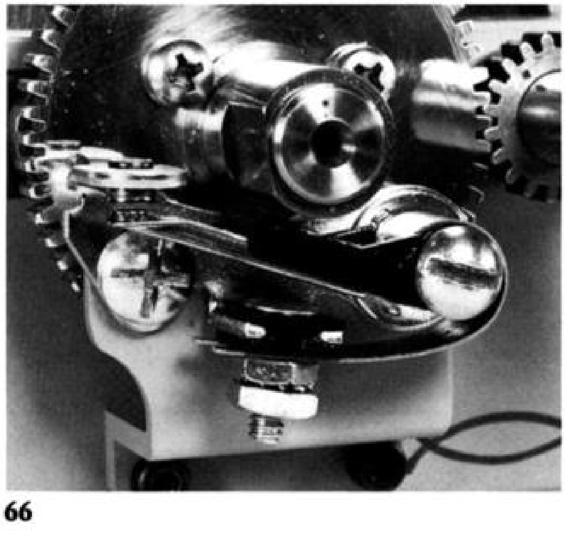
Again referring to Photo 44, loosen the cap screws that hold the ignition cam to the gear. Now bolt the Ignition Bracket in place (Photo 65) followed by the breaker point set (Photo 66).


No. 43 drill
3 holes
1¼" dia.
1³⁄₃₂" BC
⁵⁄₁₆" dia.
60°
60°
1¹⁄₃₂
¹⁄₁₆
45°
¹⁄₁₆
¹⁄₁₆
¹⁄₁₆
three ¹⁄₃₂" thick washers
insert between units at assembly
1
¹⁄₁₆
45°
⅝
⅛
¹⁄₁₆
⁵⁄₁₆" dia.
⁵⁄₁₆-24 thread
tap 2-56 3 holes
locate from cover
1¼" dia.
¹⁵⁄₁₆" dia.
¹³⁄₆₄" dia.
drill through

MUFFLER
aluminum
1 required



65



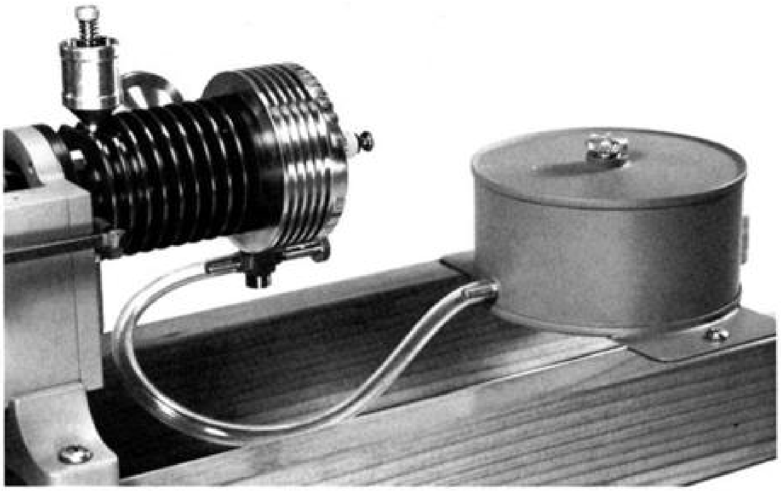
66

Adjust the points to open about .030". Have the spark plug in place so it's possible to feel the compression stroke when turning the flywheel clockwise.

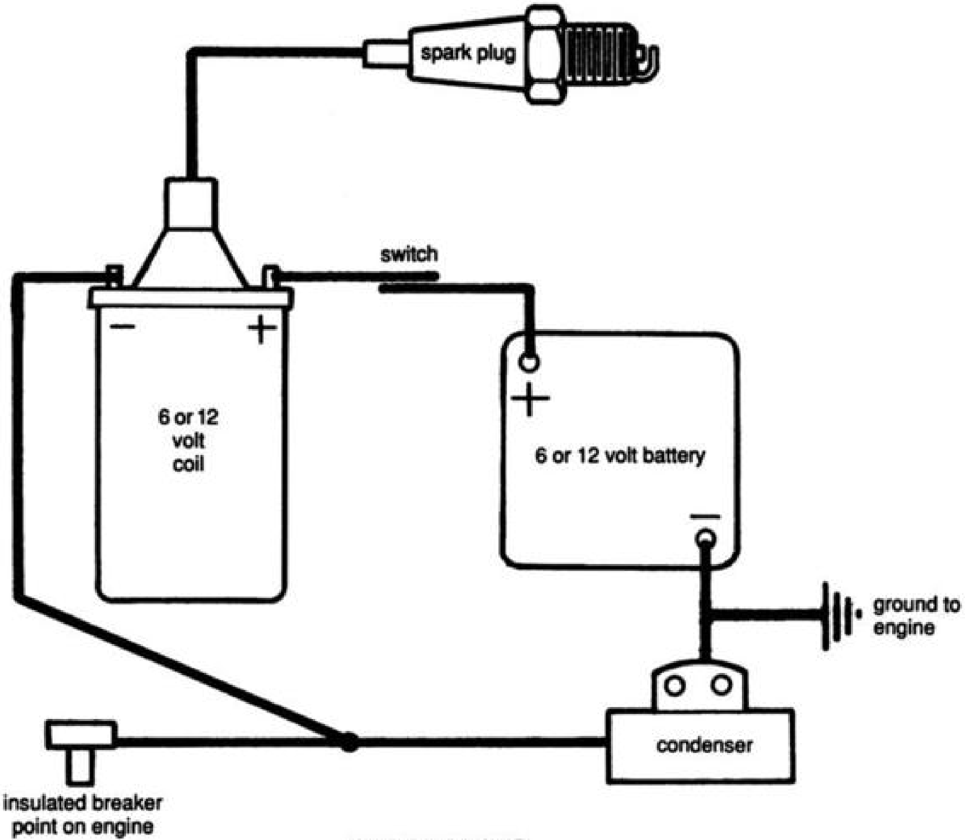
Bring the piston to the top of its compression stroke. Turn the loosened ignition cam by hand in a counterclockwise direction. The ignition points should just begin to separate after the piston has reached top dead center and started outward by about 1/32", or if you prefer, 5° rotation of the flywheel from top dead center. Now lock the three cap screws to secure the ignition cam in place.

The Gasoline Tank can be fabricated from a discarded tuna can (Photo 67). Cut out a new lid for the can, drill a central hole in it for the internally threaded filler pipe. Drill a small hole in the side of the can near the base for a short piece of brass tubing. Solder everything in place. The tank is then soldered to a flat strip of sheet metal for holding it to the wooden rails.

Finally, a Vented Filler Cap is machined for the filler pipe. Use gasoline resistant plastic tubing or neoprene rubber tubing to connect the tank to the engine. Fuel level in the tank should be no higher than about 1/8" below the height of the jet needle on the carburetor intake pipe.


67

I've found it expedient to first break in an engine by attaching the crankshaft to a lathe spindle or a drill press and driving it for half an hour or so. The spark plug should first be removed. Then, occasionally oil the moving parts. Of course, if all of your engine parts turn freely with no binding, then prepare to



IGNITION CIRCUIT

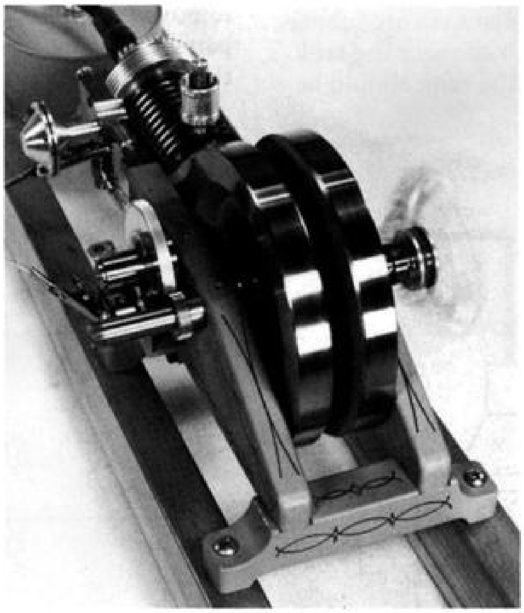
run it in under its own power. Don't expect your motor to start the first time you flip the flywheel; if it does, you've set some kind of a new record! Let's assume that the valve and ignition timing are correct, also that the compression is fairly good and the ignition system produces a good, fat spark.

The only hitch left is the correct adjustment of the needle valve in the carburetor intake pipe. This is found by trial and error, which means a lot of cranking on the flywheel. With my engine it's necessary to open the needle valve about 1-1/4 turns from the closed position to start the motor when it's cold. Every motor is slightly different, but this is a good setting to begin with. Turn on the ignition and place a finger over the intake pipe. Flip the flywheel until you notice the intake valve jerk inwards.

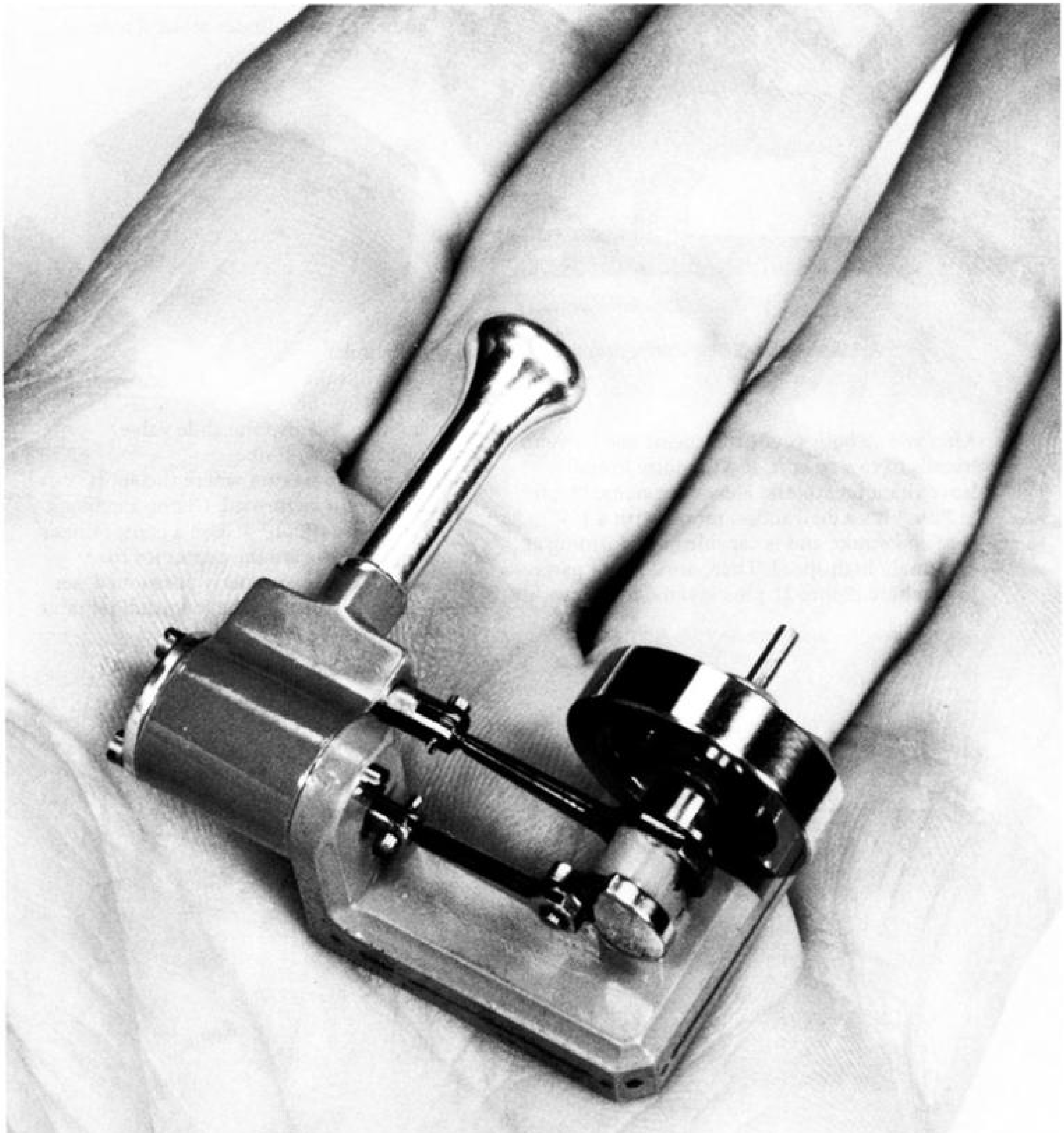
Remove your finger and crank half a dozen times more. If it begins to fire several times in a row and then dies, it could mean it's receiving too much fuel – or not enough. Remove the spark plug and examine the tip. If it has a wet appearance, close the needle valve about a quarter turn; if it appears dry, open the needle valve a quarter turn. Another cause of a balky engine could be a spring on the governor that is too weak, causing centrifugal force to activate the governor too soon and kill the engine before it has reached enough speed to keep running.

When the engine is running and has warmed up, the needle valve can be fine tuned to a leaner mixture of fuel – usually about a quarter turn clockwise. Keep the cylinder oiler bowl about ¾ full. Bubbling in the oil is normal when the engine is in motion (caused by compression leak). Close the valve on the oiler when not in use, but be sure to open it a turn or so when the motor is in operation!

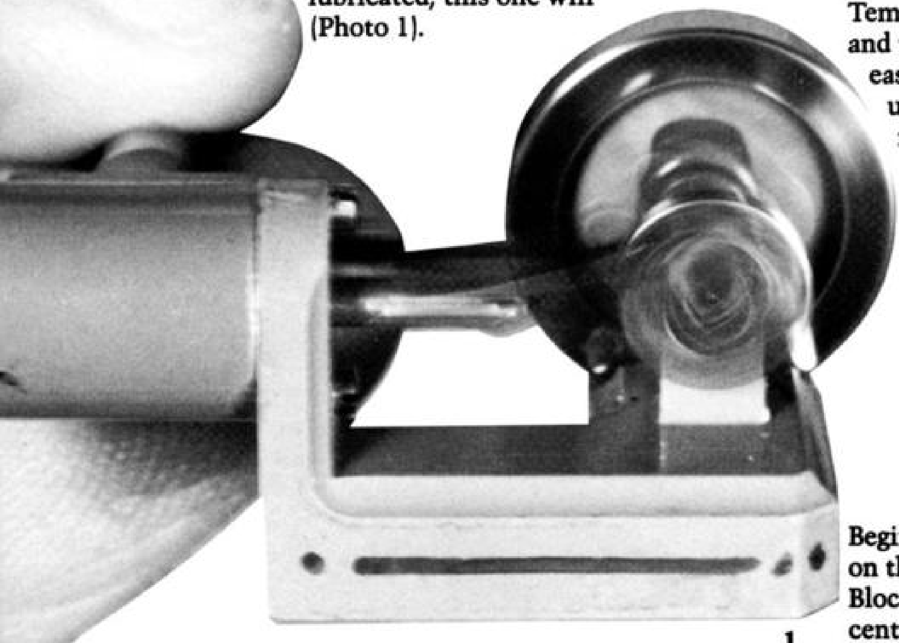
Oh yes, one thing more! At the present time I'm the only guy in the world with one of these engines, so if you want to be the number two person, you'd better get to work right away!



A Huff 'n Puff Engine



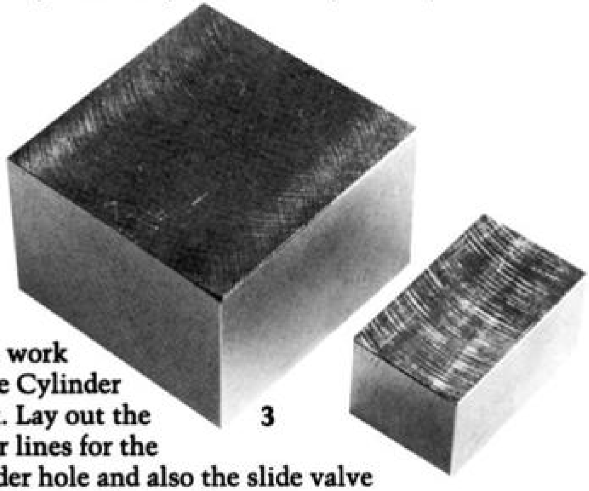
Please! Before you say, "What? another steam engine?," you should know that *this* one is somewhat different than "run of the mill" model engines. Its diminutive size is rather unusual, but how many engines have you seen that will operate on *breath* power? When properly constructed and lubricated, this one will (Photo 1).



1

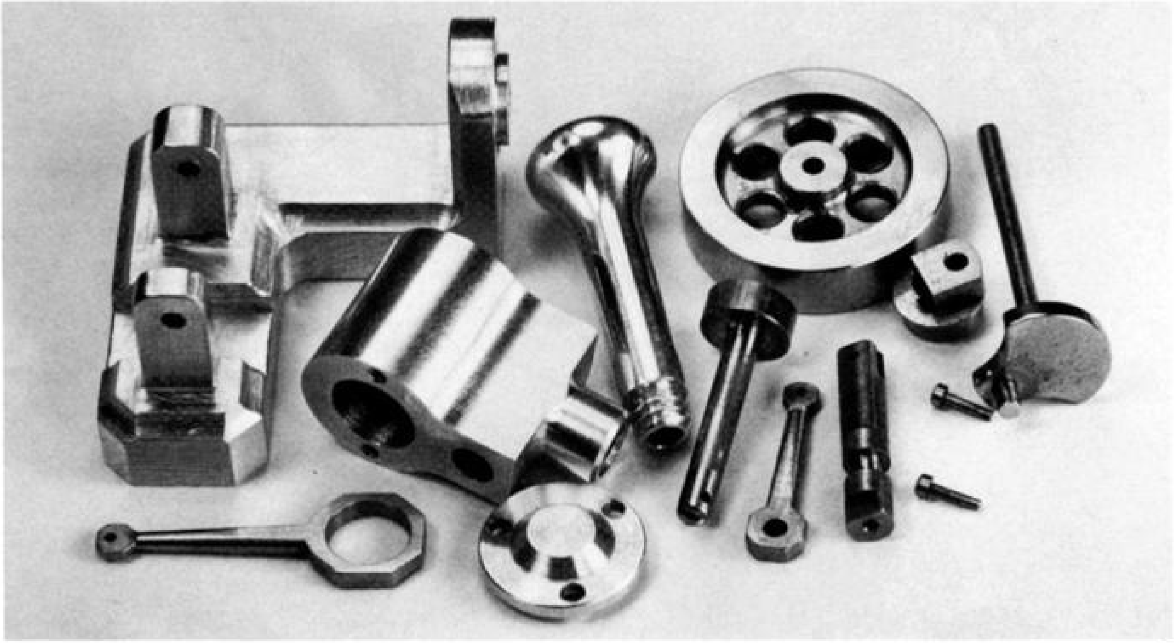
After you've built your little engine and let your friends have a go at it, it will, quite literally, leave them breathless! Hence the name "Huff 'n Puff." It's a dual action motor with a 1/4" bore and stroke and is capable of performing at extremely high speed. There are only 14 parts to machine (Photo 2), plus seven 0-80 screws to hold the motor together. This is by no means the smallest engine ever constructed; however, it is small enough to present a nice challenge. Remember, any reduction in the size of a motor increases the necessity for close tolerances and *smooth* finishes on all moving parts. You'll discover this to be a fascinating project!

Tempered aluminum was utilized for the body and the cylinder block simply because it's easier to machine. CRS or brass could also be used. First, machine two accurate blocks of metal to the overall dimensions of the body and the cylinder block (Photo 3).



3

Begin work on the Cylinder Block. Lay out the center lines for the cylinder hole and also the slide valve hole. Next to that, scribe the lines for the section where the short intake pipe will be formed. Clamp the block in the mill vise (Photo 4). Use a center finder or "wiggler" to locate the center for the cylinder hole; when properly positioned, set the calibrated collar on the longitudinal table

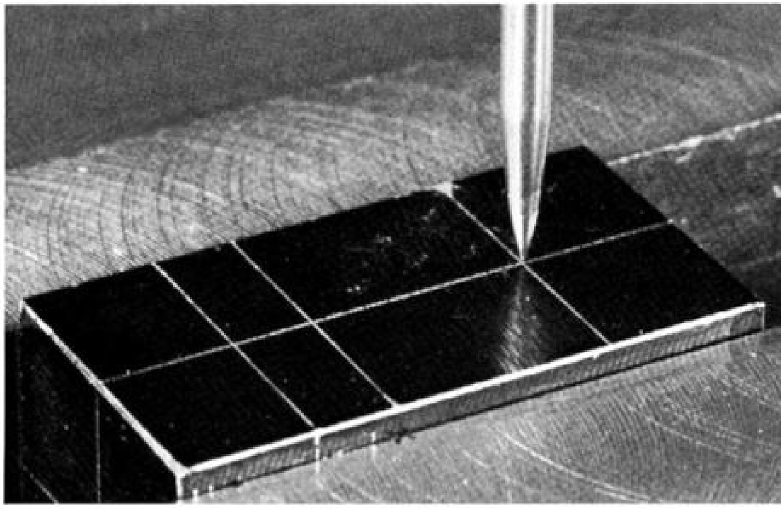


2

travel to zero. Then center drill, drill, and ream the hole all the way through the block.

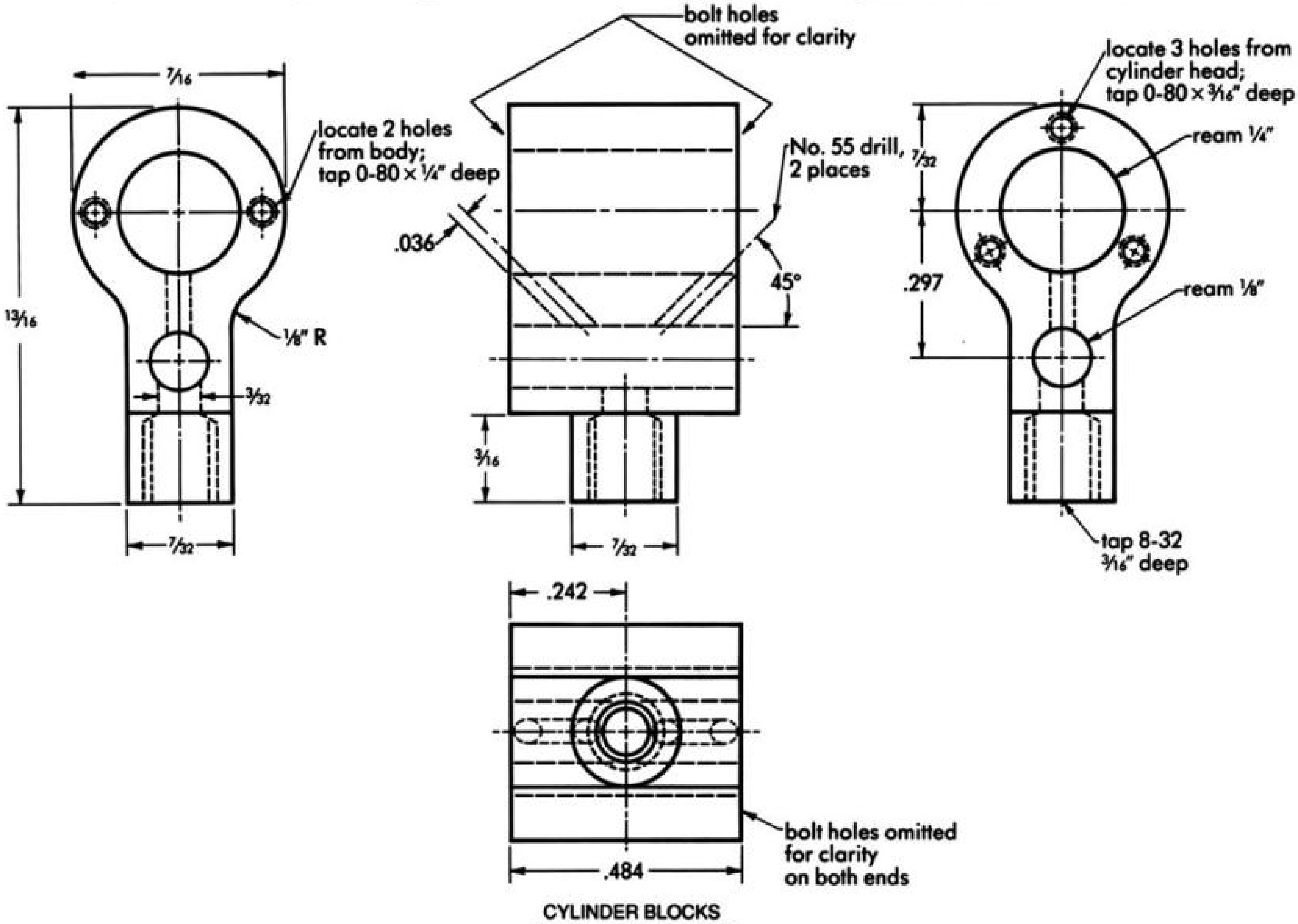
Now move the table the specified distance to center over the spot for the slide valve hole. Be precise. Drill and ream the hole through the block. Referring to Photo 5, tilt the cylinder block *exactly* 45° by use of an accurate angle block. Locate the wiggler directly over the sharp edge of the bore. Now move the table to the left .036". This will be the position for drilling the first port hole from the cylinder down into the slide valve cylinder.

In order to drill accurately, it's necessary to spot face the location first (Photo 6). Use a 1/16" end mill to flatten the area before drilling. Follow with a small center drill and then drill through to the slide valve hole. Caution! When the drill breaks through into the slide valve hole, don't allow it to extend so far as to hit the opposite side. Now reposition the work in the vise and repeat the procedure to drill an identical port hole in the opposite end of the cylinder. Proceed by machining the intake pipe section (Photo 7). Again, use caution when drilling into the slide valve cylinder. Don't allow the drill to touch the opposite side of the slide valve hole.

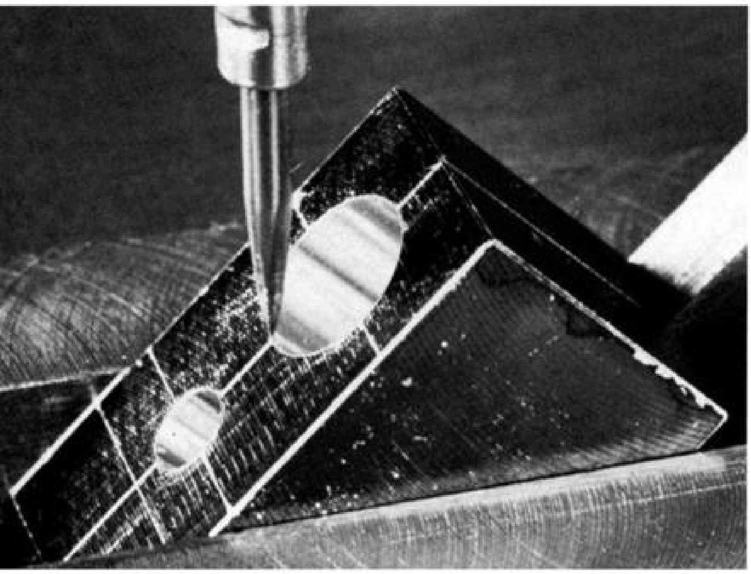


4

When this operation is completed, two options are possible. The cylinder block can be left in


bolt holes omitted for clarity
7/16
13/16
locate 2 holes from body; tap 0-80 × 1/4" deep
1/8" R
3/32
7/32
.036
No. 55 drill, 2 places
7/32
45°
3/16
7/32
locate 3 holes from cylinder head; tap 0-80 × 3/16" deep
ream 1/4"
.297
ream 1/8"
tap 8-32 3/16" deep
.242
bolt holes omitted for clarity on both ends
.484

CYLINDER BLOCKS
aluminum, brass or CRS
1 required



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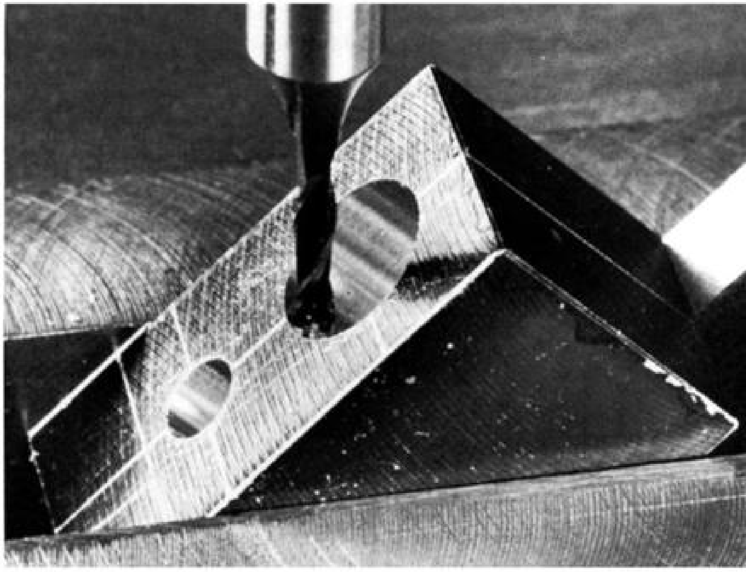

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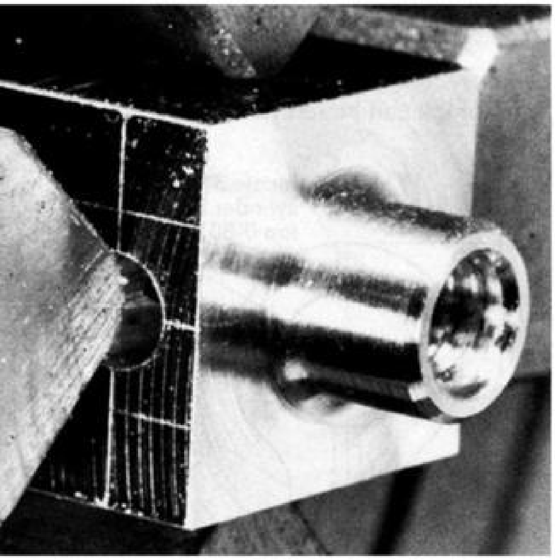

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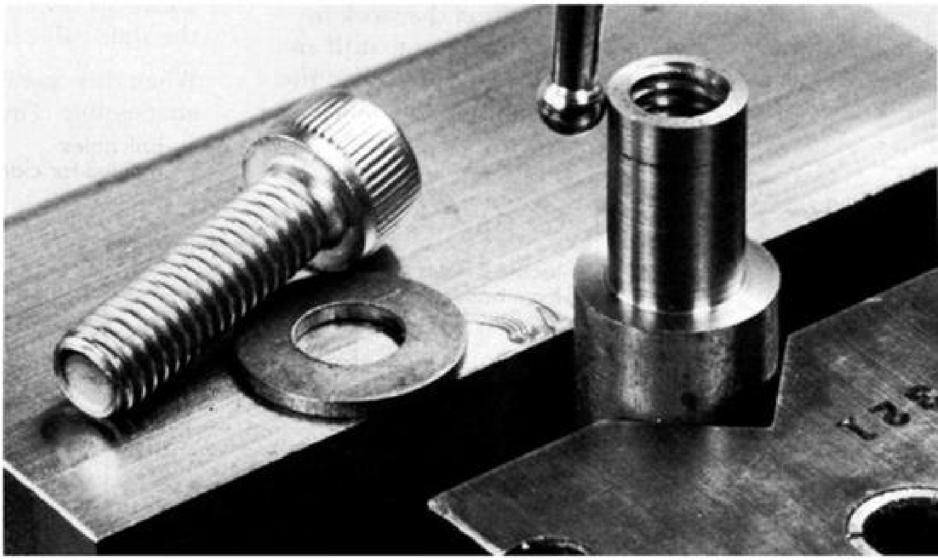

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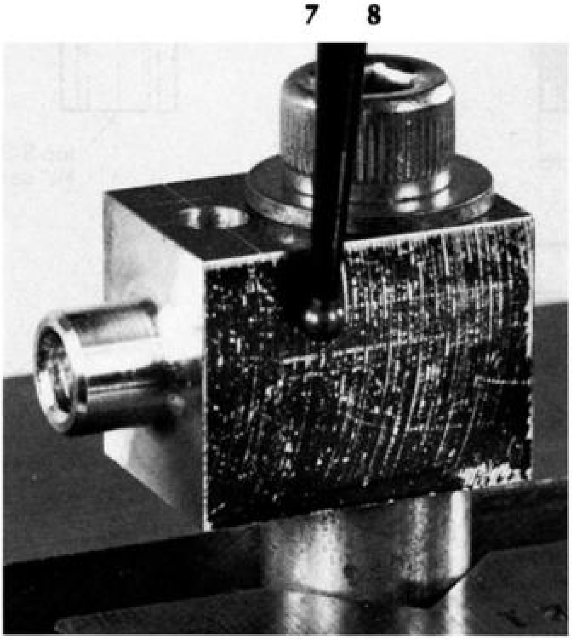

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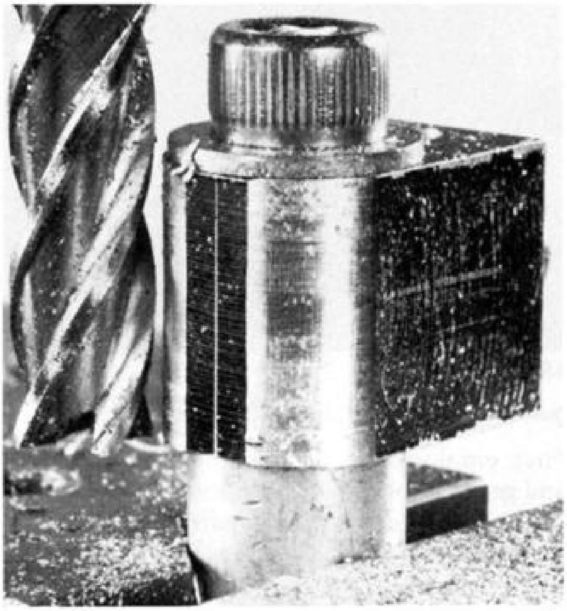
its present squarish configuration or it can be contoured to a more conventional appearance. If you wish to contour it, machine out a simple fixture (Photo 8). Use a piece of 3/8" CRS about 1-3/4" in length. Machine a portion of it to about .2498" in diameter and about 7/16" long. A 10-32 thread is tapped in the fixture hole; when completed, mount a rotary table on your milling machine and accurately center it true to the mill spindle.

Secure the fixture in a small vise and place it on the rotary table. Adjust the location of the vise until the fixture is centered true to the spindle, then clamp the vise securely to the rotary table. Now crank the rotary table to bring its pointer to the zero degree setting. Mount the cylinder block on the fixture (Photo 9). *Lightly* tighten the fixture bolt onto the



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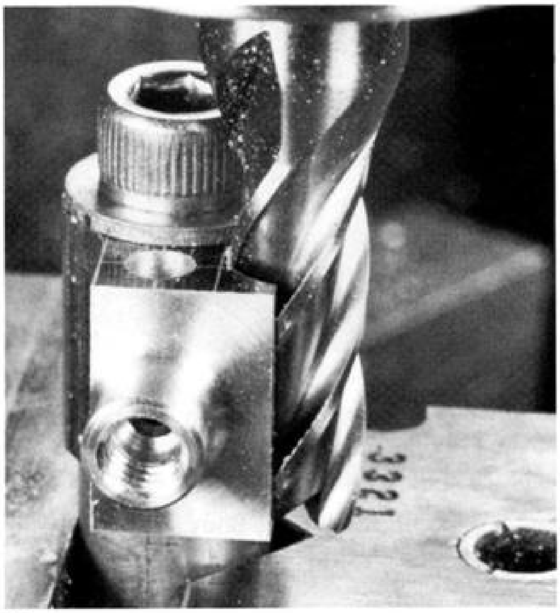
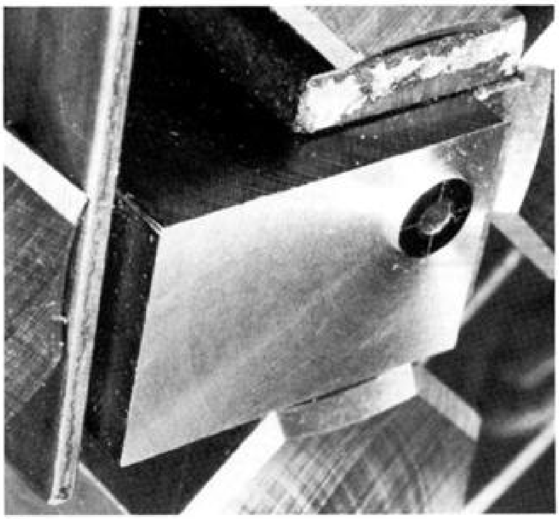


11

work. Install a dial indicator in the mill spindle, then turn the workpiece by hand until its broad side seems fairly well in line with the longitudinal table travel. Now run the indicator along this surface until, by gently nudging the work this way or that, it is running perfectly parallel; then securely tighten the fixture bolt. Again check for parallelism to verify that the bolt tightening hasn't thrown off the adjustment.

The rotary crank is employed to mill off the two sharp corners (Photo 10). Use a *sharp* 1/4" end mill and gradually mill inwards about .005" at a time; heavier cuts may cause the work to slip from its set position on the fixture. For now, do not completely round off the two corners; leave them slightly unfinished.

With the cutter in the same position, begin to slowly mill the curves on the opposite sides of the cylinder block (Photo 11). At this time, do not allow the cutter to mill exactly to the scribed layout lines on the valve side of the cylinder block; stay away about 1/64". After rough milling the curve around the block almost from one line to the other, gradually mill inwards to form a smooth circular surface. Stop as soon as all flat areas around this section have been eliminated. Now slowly mill the curve to bring it flush with the scribed line on each side. Then move the cutter away from the work. Crank the rotary table around to its zero degree setting and lock it. This should bring the cylinder block back parallel to the mill table. Use the longitudinal feed to slowly and carefully mill off the surplus metal down to the layout lines. Take very light cuts and



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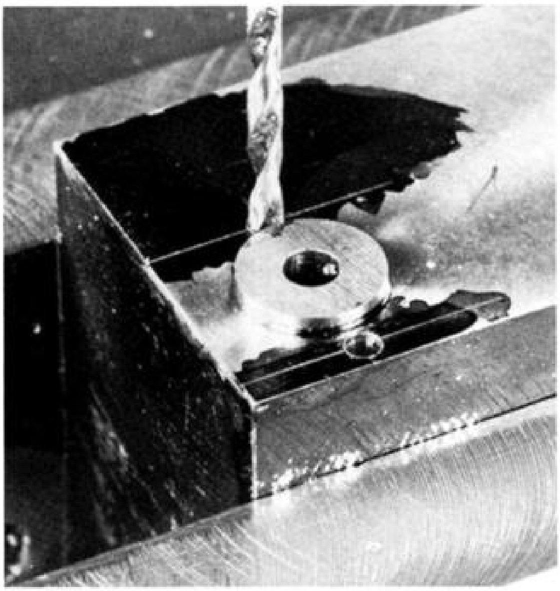

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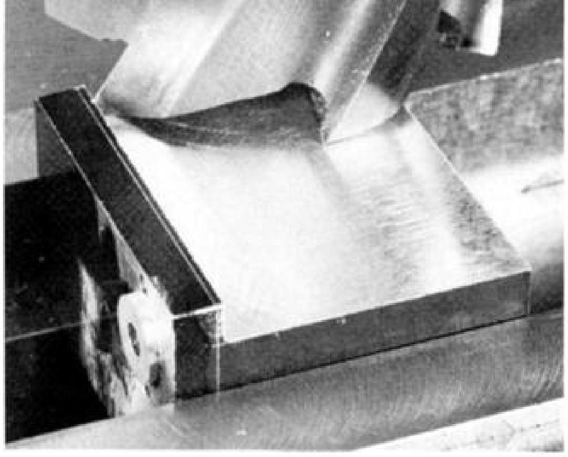

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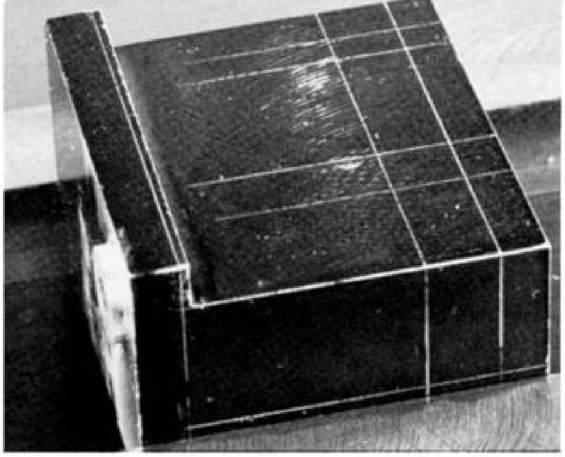
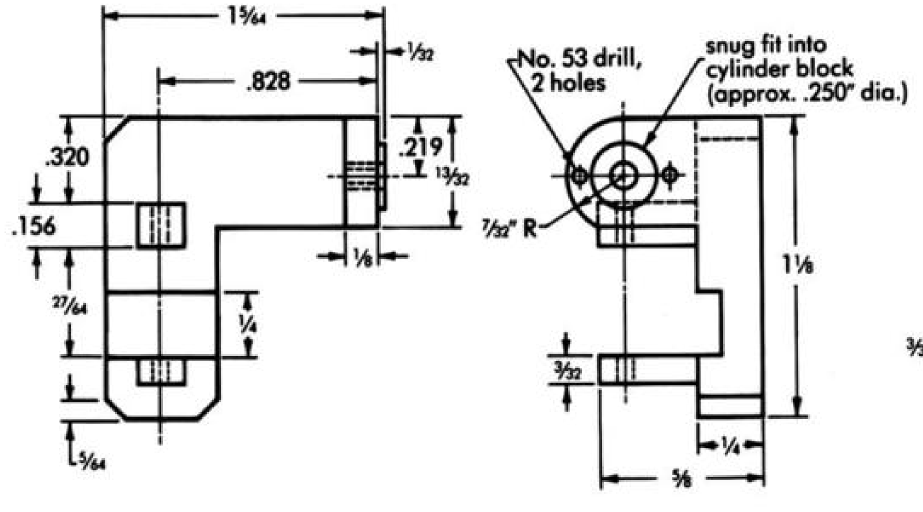


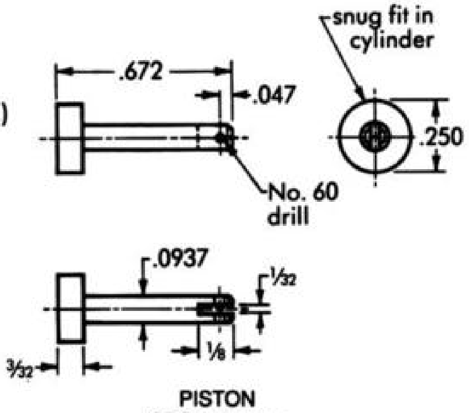
15

finally blend the straight portion into the radius of the circular section. Finally, remove the cylinder from its fixture and set it aside for now.

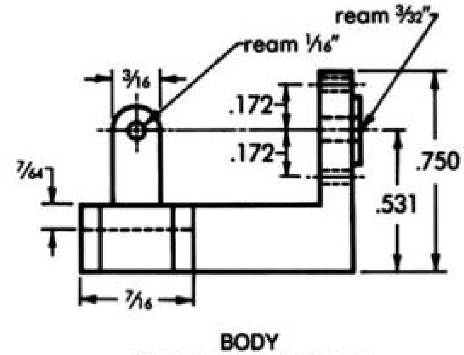
Begin work on the Engine Body. Accurately lay out cross lines for the location of the piston rod hole. Caution! The body block is almost as long as it is wide, so double check to insure that the layout lines are on the correct side of the block. Then use a four-jaw chuck to precisely center these cross lines in the lathe. If your chuck jaws are sharp edged, use padding to protect the block (Photo 12).

First, employ a No. 2, or smaller, center drill and gently spot the location for the 3/32" piston rod hole. It's *very* important that this hole about to be drilled runs as true as possible. Begin drilling with an accurately sharpened 5/64" drill. Never allow the drill to bang into the workpiece. Slowly advance the drill until it gently touches the previously drilled center hole. Use cutting oil – sulfur base oil will do in a pinch. Now slowly begin drilling. Drill the

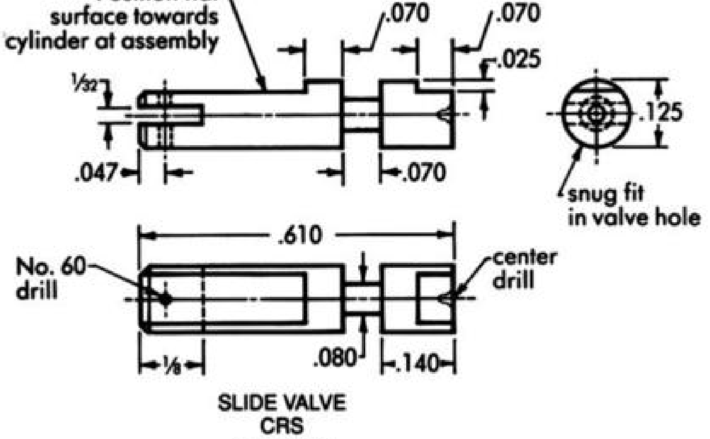

1⁵⁄₆₄
1/32
.828
.320
.219
13/32
.156
1/8
27/64
1/4
5/64
No. 53 drill, 2 holes
snug fit into cylinder block (approx. .250" dia.)
7/32" R
1⅛
3/32
1/4
5/8


snug fit in cylinder
.672
.047
.250
No. 60 drill
.0937
1/32
3/32
1/8

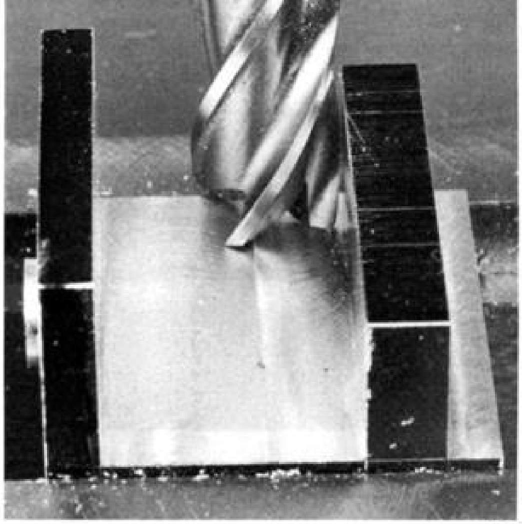
PISTON
CRS or bronze
1 required


ream 3/32"
ream 1/16"
3/16
.172
.172
.750
7/64
.531
7/16

BODY
Aluminum, steel or brass
1 required


Position flat surface towards cylinder at assembly
.070
.070
.025
1/32
.125
.047
.070
snug fit in valve hole
.610
No. 60 drill
center drill
1/8
.080
.140

SLIDE VALVE
CRS
1 required



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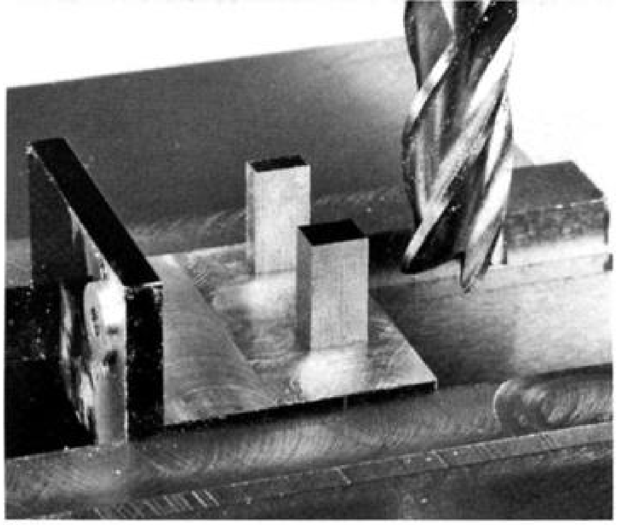


17

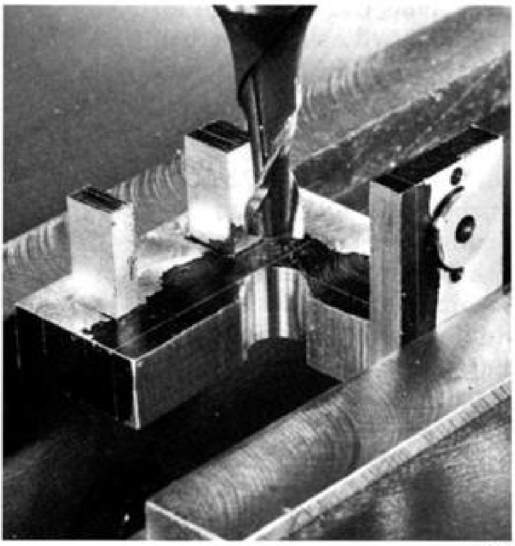
hole about 5/16" deep. Carefully enlarge the hole with a No. 43 drill, and finally ream or drill it to 3/32".

Begin machining the circular "collar" around the hole. This will be used to locate the cylinder block against the body. The diameter of this collar should be a very close fit into the cylinder hole. Then remove the work from the lathe and lay out the center lines for the two 0-80 clearance bolt holes (Photo 13). Mount the work in the mill vise and, with the aid of a wiggler, accurately center up each cross line. A No. 53 drill is used to drill the two holes about 1/4" deep.

Proceed by laying out the guide lines for the overall height of the two vertical crankshaft bearing pillars. Also, the guide lines for the vertical wall where the cylinder block will eventually be bolted. Mill down to the horizontal line (Photo 14). Stay slightly away from the vertical layout line at this time. Next, scribe the lines for the base thickness (or height) and also the location of the two vertical bearing pillars (Photo 15). Use an end mill no larger than 3/8" and proceed to mill down to the base lines (Photo 16). Once this line is reached, do not alter the height adjustment of the end mill. Now cut the two vertical walls visible in the photo to their proper thickness. Then proceed by milling the two bearing pillars (Photo 17). Remove the work and lay out the lines that will transform the square body shape into an L-shaped piece. Roughly hacksaw out the unwanted portion and secure the work in the mill vise (Photo 18). With a 3/16" end mill, from a curved slot up to the inner corner guide lines. Reposition the work as in Photo 19. Mill down to the guide lines taking care to render it flush with the curved radius in the corner.

Photo 20 illustrates a method of machining a decorative radius around the Base with a 3/16" ball end mill; this is optional.

Be precise when laying out the center lines for the crankshaft holes in the pillars. Use the milling machine to ream or drill the 1/16" hole through both pillars.



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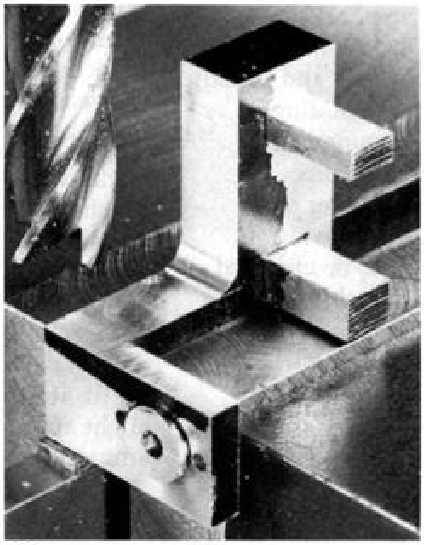
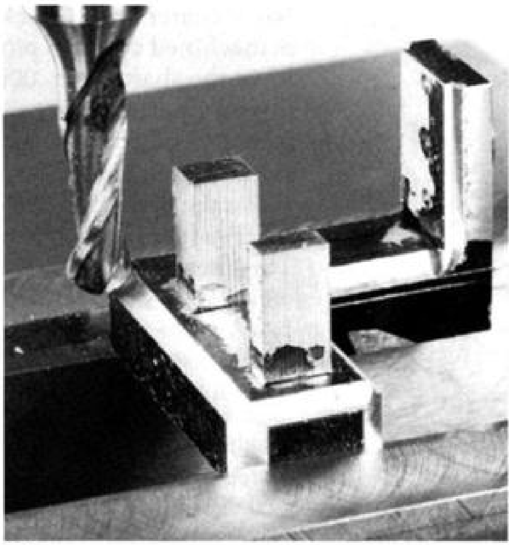


19



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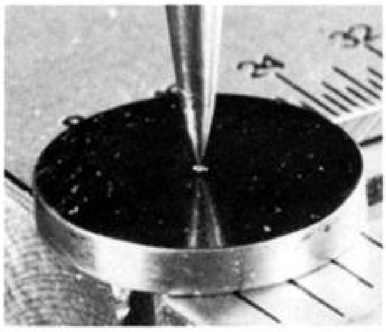

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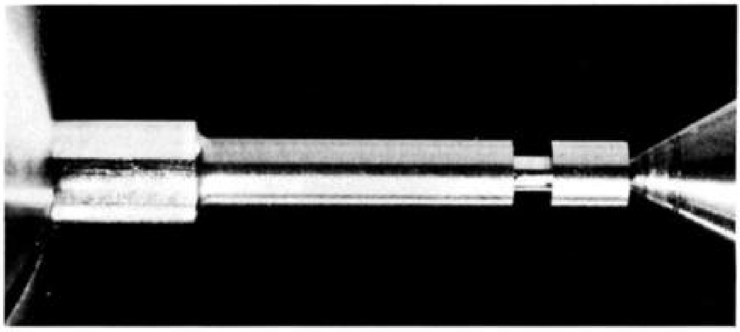

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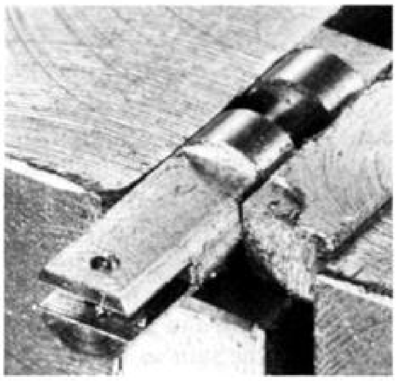

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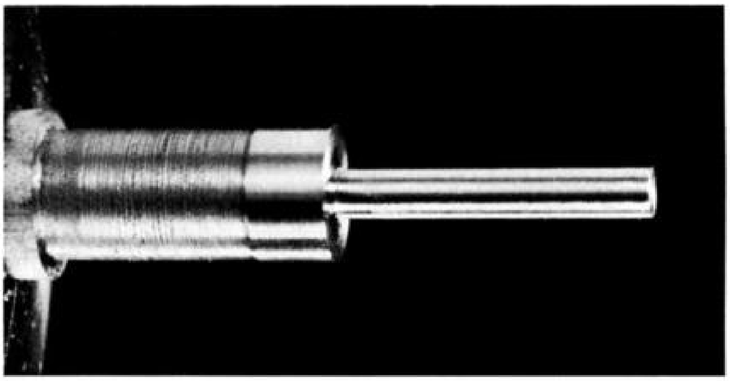


24

Now place the cylinder unit onto its locating "collar" on the body piece. Check to verify that it is squarely positioned, then clamp it tight to the body. Spot drill the location for the two 0-80 threaded holes to be drilled and tapped into the cylinder wall. Tap drill (No. 56) about 1/4" deep. The upper square end of the body where the cylinder is located can be rounded off either by hand filing or machining with the aid of a rotary table and milling machine.

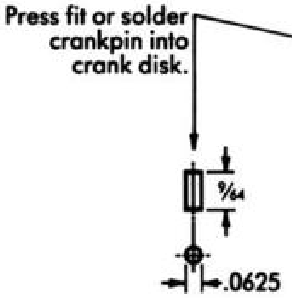
The Crankshaft is easily machined in the lathe. The shaft section, after roughing it down to about 1/8" diameter, will have to be supported with the tailstock. Center drill the end with a No. 0 center drill. Check for taper as the shaft is machined down to proper size. Preferably, leave the shaft about .0005" oversize and polish it with fine emery paper for a free sliding fit into the body bearing holes. Then part the crankshaft and disk from the stock piece. Leave the disk portion slightly thicker than specified for facing off in the next operation. This means the work will have to be chucked on its 1/16" diameter shaft. Preferably, use a 1/16" collet to hold it; otherwise, gently chuck it in a three-jaw chuck. Excessive chuck pressure may squash the shaft out of round.

Machine the face of the disk, bringing it to the correct thickness. Apply layout blue to the outer face. Insert a No. 0 center drill in the tailstock, start the lathe, and very carefully advance the center drill to barely scratch a center spot in the blueing. Transfer the crankshaft to the mill vise (Photo 21). Note the two rules acting as thin parallels by supporting the disk. They are necessary because of the little step shoulder located on the other side of the disk. A portion of the crank disk should extend beyond the vise so, when the crankpin hole is drilled through in that location, it will clear the vise jaws. *Do not* overtighten the vise onto the crankshaft.

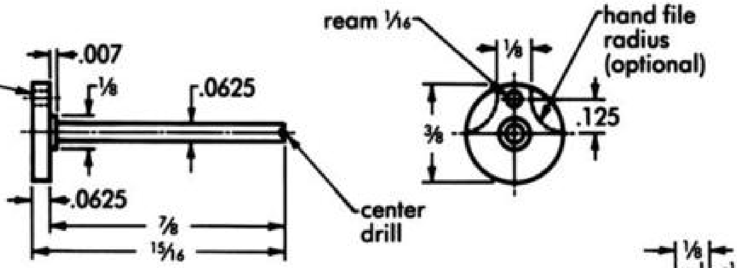
Position the mill spindle directly over the work center. Set the collar on the longitudinal table travel to zero. Now move the table the specified distance to the right, center drill, and carefully drill and ream a 1/16" hole. Use cutting oil to avoid an oversize hole. I used a short length of hardened 1/16" dowel pin for the crankpin and pressed it in place. If the crankpin hole is oversize, then solder the pin in place.

Begin work on the Slide Valve (Photo 22). Machine the shaft about 1/8" longer than specified for easy cutoff later on. Before cutting the groove in the shaft, bring the diameter of the shaft to correct size for a close fit into the slide valve hole in the cylinder unit. The shaft must have a smooth finish, and when testing for fit, it should slide into the hole with a very slight amount of resistance. Apply a small amount of oil when testing to avoid scoring.

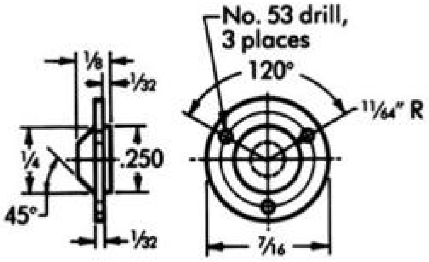
Now, by positioning the compound slide of the lathe parallel to the workpiece, the position of


Press fit or solder crankpin into crank disk.
9/64
.0625

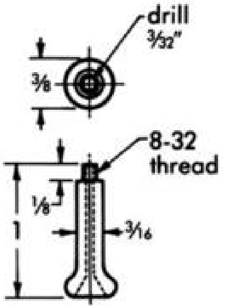
CRANKPIN
CRS
1 required


.007
1/8
.0625
.0625
7/8
15/16
center drill
ream 1/16
1/8
hand file radius (optional)
3/8
.125

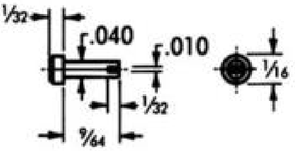
CRANKSHAFT
CRS
1 required


No. 53 drill, 3 places
1/8
1/32
120°
11/64" R
1/4
.250
45°
1/32
7/16

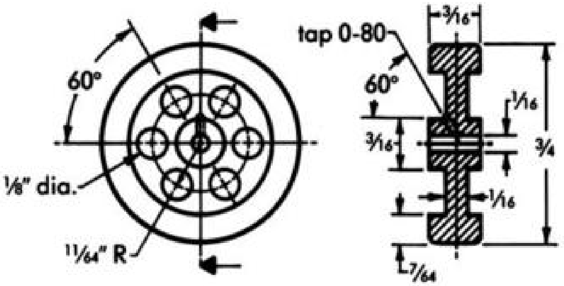
CYLINDER HEAD
brass
1 required


drill 3/32"
3/8
8-32 thread
1/8
1
3/16

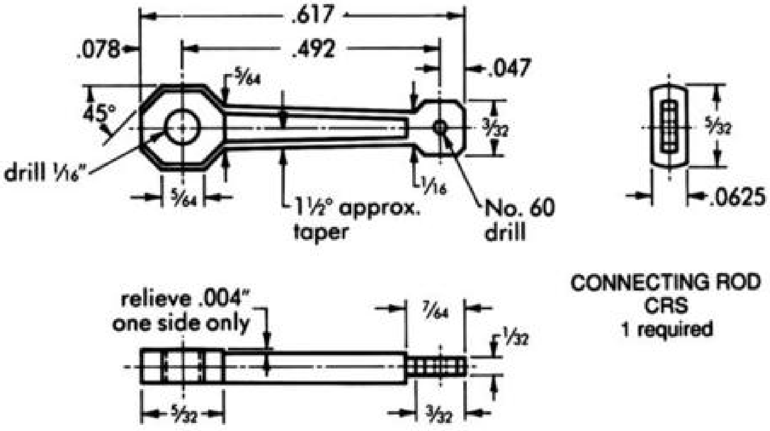
BLOWPIPE
alluminum
1 required


1/32
.040
.010
1/16
1/32
9/64

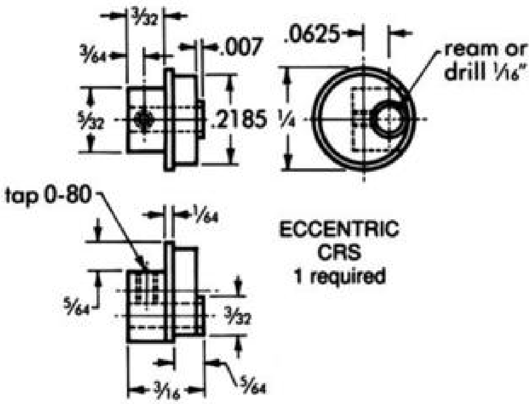
WRIST PIN
CRS
2 required


60°
1/8" dia.
11/64" R
tap 0-80
3/16
60°
1/16
3/16
3/4
1/16
7/64

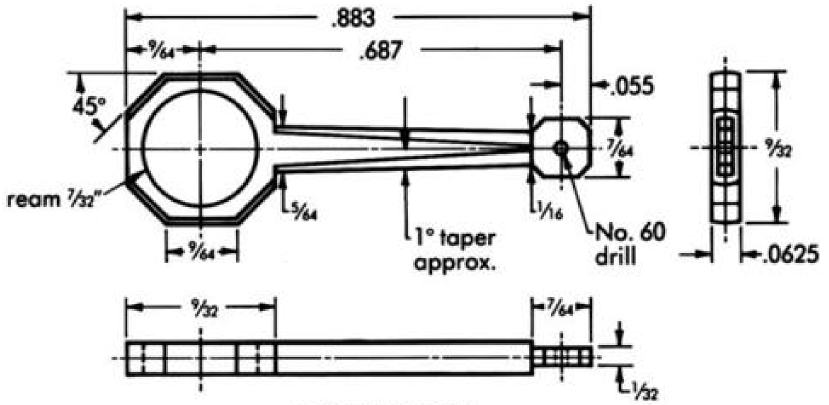
FLYWHEEL
CRS
1 required


.617
.078
.492
.047
5/64
45°
3/32
drill 1/16"
5/64
1/16
1 1/2° approx. taper
No. 60 drill
5/32
.0625
relieve .004" one side only
7/64
1/32
5/32
3/32

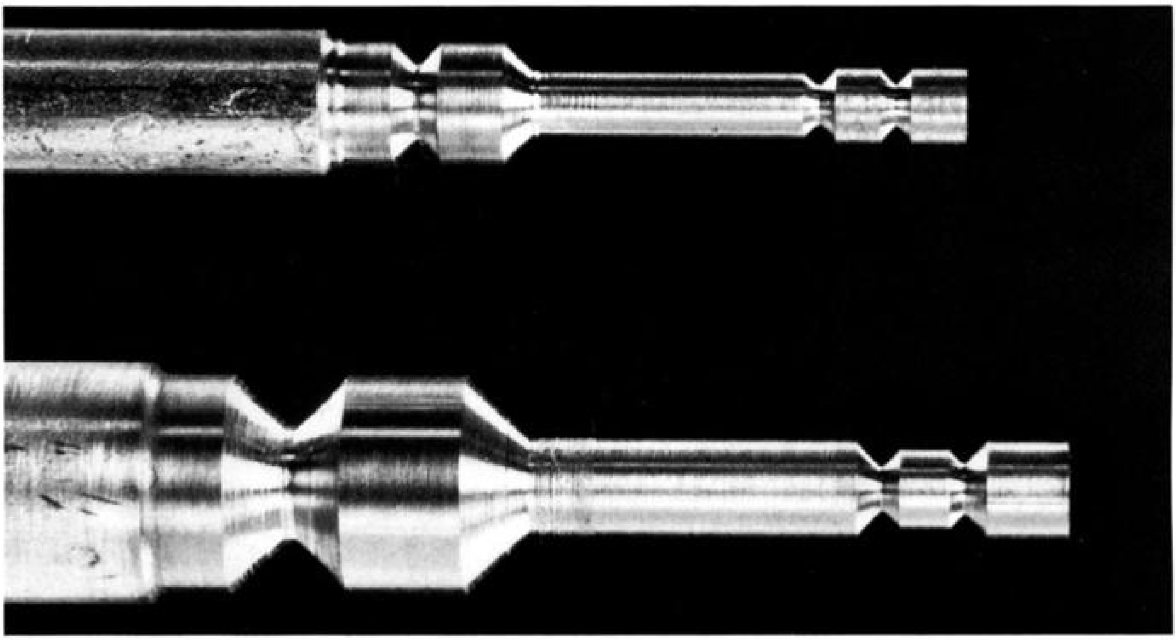
CONNECTING ROD
CRS
1 required


3/32
3/64
.007
5/32
.2185
.0625
ream or drill 1/16"
1/4
tap 0-80
1/64
5/64
3/32
3/16
5/64

ECCENTRIC
CRS
1 required


.883
9/64
.687
.055
45°
7/64
ream 7/32"
5/64
1/16
9/64
1° taper approx.
No. 60 drill
9/32
.0625
9/32
7/64
1/32

ECCENTRIC ROD
CRS
1 required



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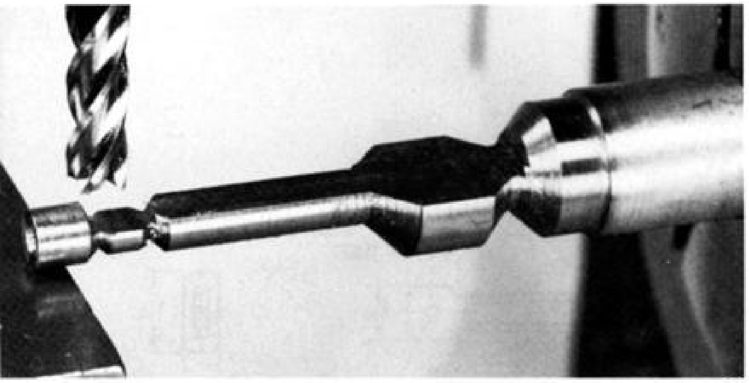
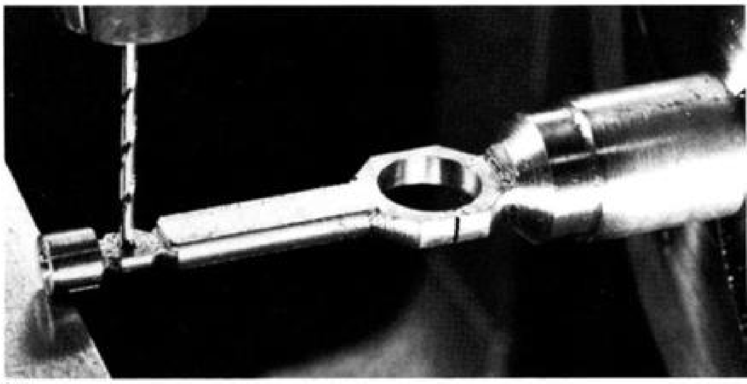


26



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the groove in the slide valve can be precisely located and cut. The slide valve is then cut off *exactly* to the proper length. The following operations on the shaft are performed in the milling machine. Use a parallel in the vise to locate the workpiece just high enough for the milling cutter to clear the vise jaws. The setup is visible in Photo 23. Note the short length of 1/8" square stock used as a "sacrifice" clamping parallel to hold the shaft. First, drill the wrist pin hole in the outer end of the shaft. Locate it accurately with the aid of an edge finder. A 1/32" thick circular slitting saw is employed to cut the slot.

One method of doing this fairly accurately is to lower the slowly revolving saw and position its cutting teeth about 1/32" over the end of the shaft. Slowly lower the saw until it just barely scratches the work. If you prefer, apply layout blue first to the shaft for better visibility. Then back off the saw and lower it half the diameter of the work plus half the thickness of the saw. Cut the slot. Mill the flat sections on each end of the shaft with a 1/8" end mill. Remove the work and *carefully* remove all burrs from the slide valve.

The Piston is next (Photo 24). Undercut the stock piece behind the piston head for a distance of about 3/8". The piston shaft section can be machined without tailstock support provided the cutting tool is honed razor sharp. The tool should be rather pointed and possess a small radius honed on the cutting tip. When approaching the correct diameter for the shaft section, execute several passes back and forth with the cutting tool at the same setting; use a fine carriage travel. The shaft should be a snug fit into its mating hole in the body. So keep testing for fit; then machine the piston head for a snug fit in the cylinder. Part the piston from the stock, leaving it slightly long for facing off to the proper length. Drilling and slitting the end of the piston shaft is similar to that performed on the slide valve.

Again, remove all resulting burrs.

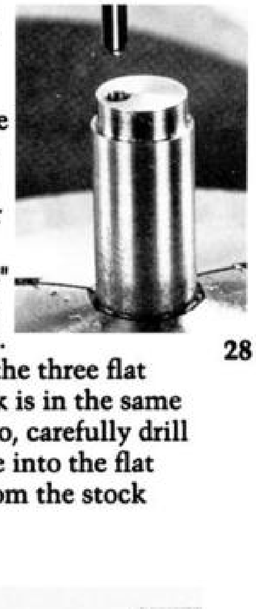
Photo 25 illustrates how the Piston Connecting Rod (uppermost) and the Eccentric Rod are first machined from round stock. The short piece of excess stock on the tip of each rod is center drilled for tailstock support and will later be cut off. The work is then chucked in an indexing fixture on the mill – or extend it outwards from the side of a mill vise. Support the tip end on an adjustable parallel.

In Photo 26, the eccentric rod is being machined with a 1/8" end mill. The upper surface has been milled to the proper depth. Note that the wrist pin end has been machined 1/64" deeper than the main body section. Now rotate the work 180° and slowly mill the other side. Take shallow cuts – .005" – to avoid flexing; in other words, be very gentle! This side is identical to the other side. In order to drill the two holes in the rod – that is, the wrist pin hole and the cam hole – it is first necessary to find the longitudinal center line of the rod; use an edge finder for this job. Now position the mill spindle over this center line and then set the calibrated collar on the cross slide at zero – thus enabling you to return to this setting at will. In Photo 27, the cam hole has already been drilled; the position of the cross center line of this hole is indicated by the short vertical line visible on the *side* of the rod. Scribe a similar line on your rod, as close as possible to the center of that short, straight section near the end of the rod.

True up a wiggler in the mill spindle and bring it to bear in line with the short vertical line just scribed on the rod. Set the calibrated collar on the longitudinal travel to zero. Insert a small center drill in the spindle chuck. Bring the cross slide back to its original zero setting. This should be the proper location for drilling the large hole. Center drill, follow with a 1/8" drill, gradually increase the drill sizes, and finally ream the hole 7/32". Now move the longitudinal table travel the specified distance, center drill, then drill the wrist pin hole. Remove the work and set it aside for the moment.

Install the connecting rod unit in the mill. The setup and procedure is similar to that of the eccentric rod. However, after milling the rod to its proper thickness, don't forget to mill one side about .004" deeper along the straight central portion of the connecting rod; this will prevent the connecting rod arm from rubbing against the side of the crank disk when properly assembled. After drilling the two holes in the connecting rod, remove it from the mill and install it once again in the lathe; support the outer end with the tailstock. Adjust the compound to 1-1/2°. *Carefully* machine the taper along the central portion of the rod, then remove it from the lathe. Use the same procedure for the eccentric rod but with a 1° taper. Finally, part them from the stock pieces, cut off the small tailstock support tips, and smooth any sharp edges with a file.

Chuck up a 1/4" round rod for the Eccentric Cam. Step cut the outer end down for a snug but free fit in the eccentric rod hole. Now transfer the work to the mill. Use a tilting head indexing fixture to hold the work in a vertical position – or a square block collet fixture could also be used for this job. With the aid of a dial indicator, center the cam directly beneath the spindle. Set the calibrated collar on the mill longitudinal feed to zero. Move the table exactly .0625" to the right (Photo 28). Center drill the work, then drill and ream the 1/16" hole about 1/4" deep. Tilt the work down to a horizontal position (Photo 29). Use a 3/16" end mill to form the three flat surfaces. Now, while the work is in the same position as shown in the photo, carefully drill and tap the 0-80 setscrew hole into the flat surface. Then part the cam from the stock piece at its correct length.



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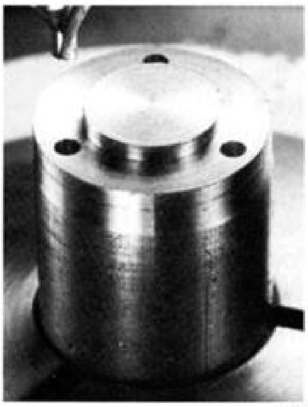
The little Wrist Pins are machined in the lathe. Leave them attached to the stock piece and transfer them to the mill for slitting (Photo 30). Then it's back to the lathe to part them from the stock piece. Later, when the wrist pins have been assembled in the engine, use a small screwdriver to *slightly* spread apart the two prongs that form the slot, thus ensuring that the pins stay in place while the motor is in motion.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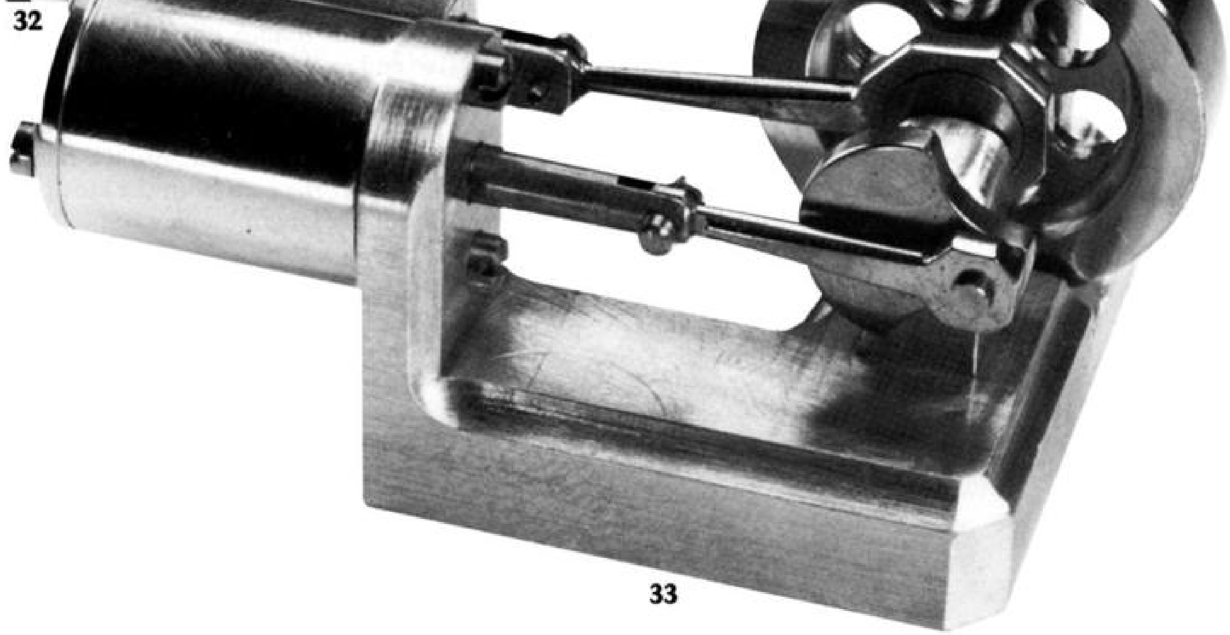
32

Prepare to work on the Cylinder Head. Machine the inner face surface first, then transfer it to the mill. Secure it in a vertical indexing fixture; if not available, then carefully lay out and scribe the three center cross lines for the bolt holes. Center drill (Photo 31), then drill the holes about 3/16" deep. Return to the lathe and part the work from the stock piece. The cylinder head is then gripped lightly in a chuck or collet on the little step shoulder or outside diameter for machining the outer face. Afterwards, place the cylinder head in position on the cylinder and spot drill the location for the three holes to be drilled and tapped in the cylinder.

Little explanation is necessary for machining the Flywheel, except perhaps about the 0-80 setscrew hole. The flywheel should be tilted about 30° for this operation (Photo 32). First, spot face the location for the hole with a 1/16" end mill before drilling and tapping.

After assembling the engine (Photo 33), the slide valve must be timed. For a clockwise rotation of the flywheel (as viewed from the crankpin side of the engine) the piston unit should be positioned at the end of the outward stroke. Refer to the photo. Now observe the position of the eccentric cam. The highest spot on the cam is placed straight up in a vertical position. To obtain an anti-clock rotation of the motor, the piston unit is placed at the end of its inward stroke – the cam is then set, once again, exactly as positioned for the clockwise rotation. There are two "dead" spots where *no* power is exerted against the piston; at the inner and outer end of each piston stroke. Whenever the piston is in either of these locations, it's necessary to give the flywheel a little push to start the motor.

For proper performance, the engine must be "broken in." Gently secure it to a lathe spindle or a drill press spindle for motive power. Ordinary household *3 in 1* or light motor oil can be applied to lubricate the engine. Run the motor for at least an hour at about 800 rpm; oil it occasionally. The idea is to free the engine of all binding or excessive friction caused by snug fitting parts. If an air compressor with a pressure regulator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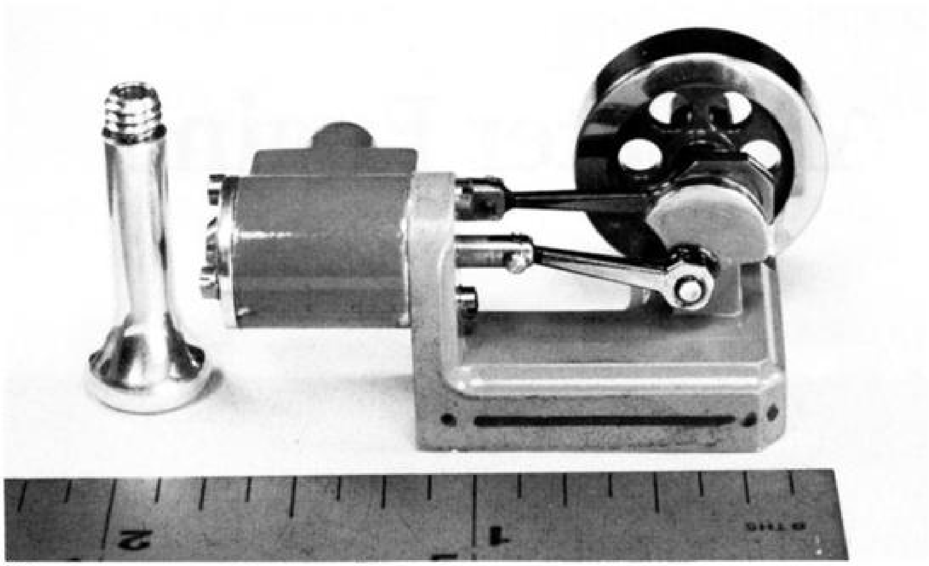

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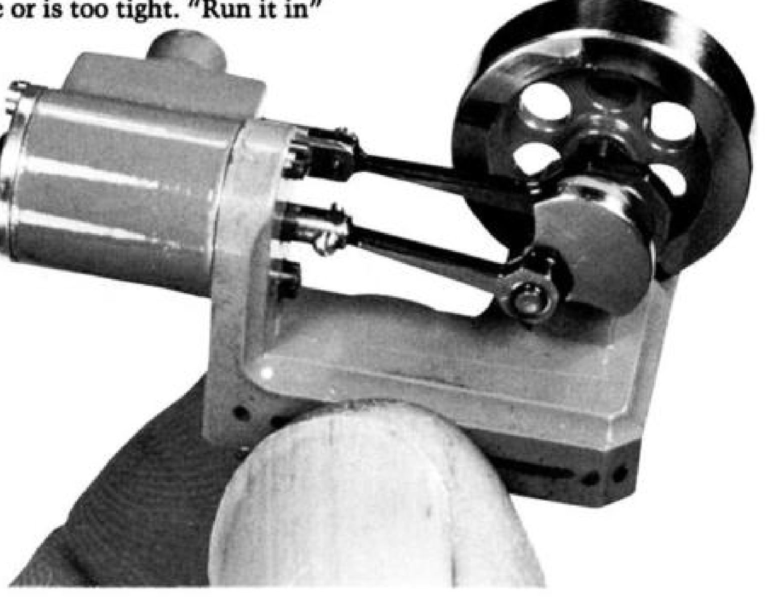
is available, that could also serve to "break" it in.

While developing this little guy to operate on "Huff 'n Puff" power, it became distressingly apparent that ordinary lubricants are all *too* heavy or thick! Many "super" lubricants were tested, including instrument oil and jeweler's watch repair lubricant – all too thick! The problem was happily resolved by, believe it or not, applying ordinary diesel engine fuel or charcoal lighter fluid as a lubricant!

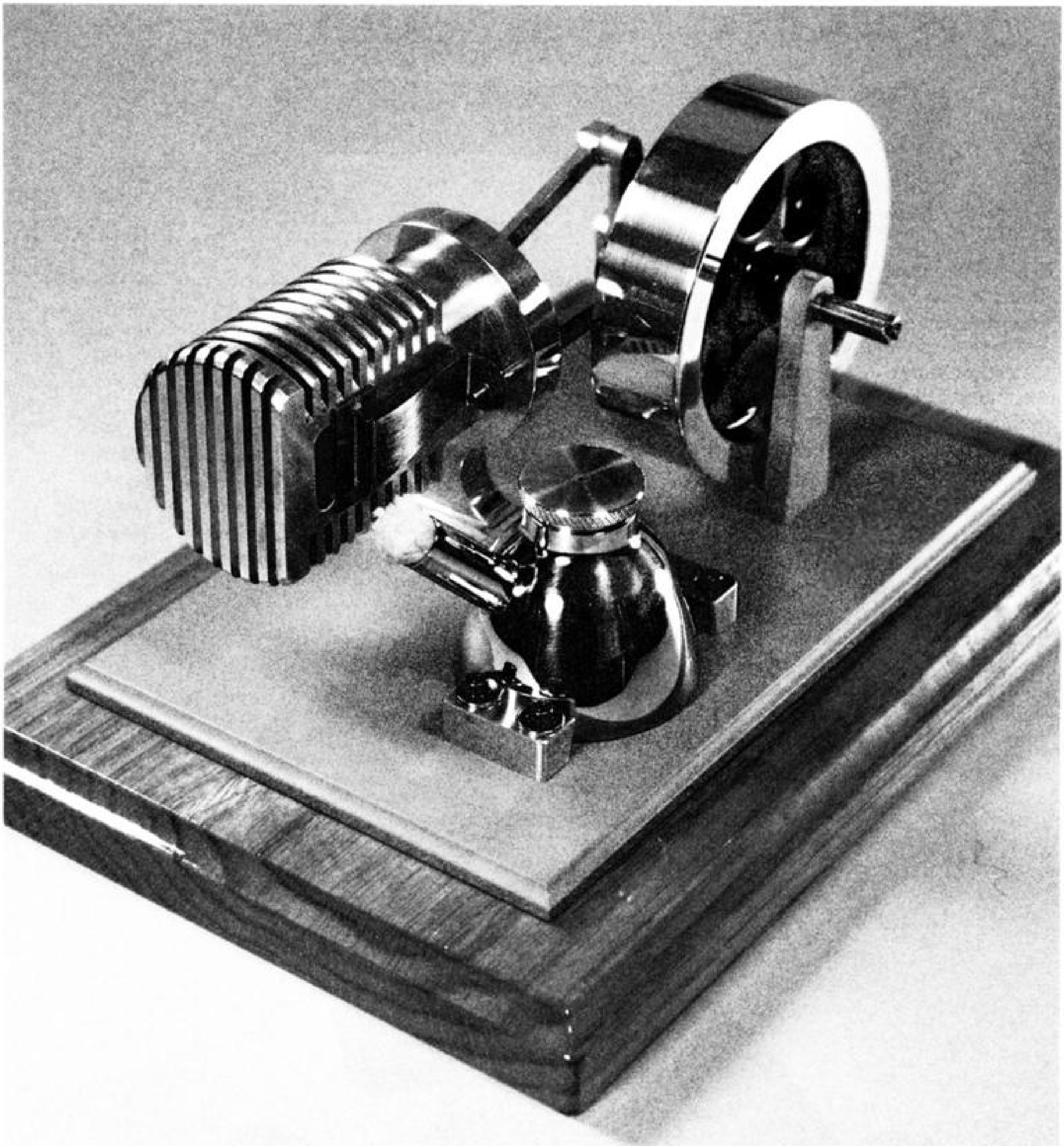
So if you wish to operate the engine on "Huff 'n Puff" power, thoroughly clean *all* heavy oil from the moving parts of the motor. Then apply a fair amount of diesel fuel to the engine parts, or as a second choice, charcoal lighter fluid. The motor should then run quite briskly on "mouth" power. If not, the engine is still binding somewhere or is too tight. "Run it in" some more.

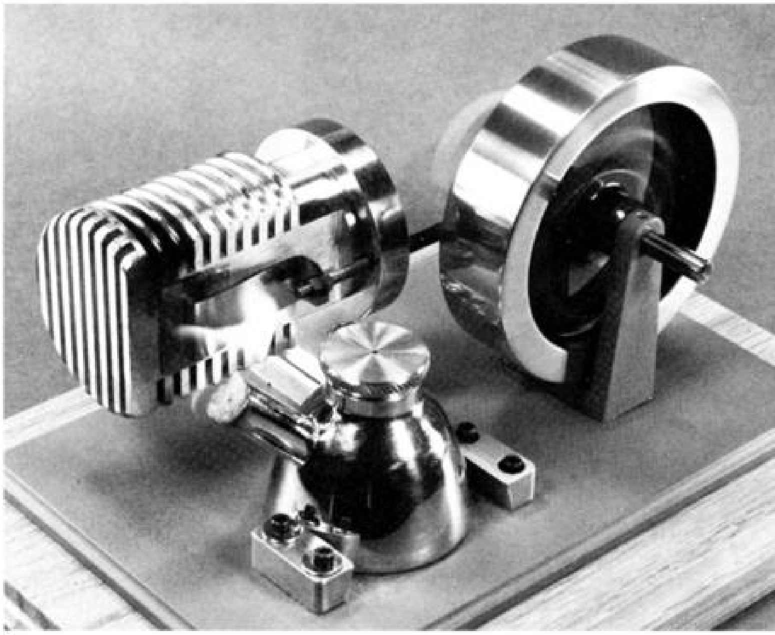
BILL OF MATERIALS

QUANTITY	PART	MATERIAL	FINISHED SIZES
1	Cylinder block	aluminum	7/16 × 31/64 × 13/16"
1	Body	aluminum	3/4 × 1 1/8 × 1 5/64"
1	Piston	CRS rod	1/4 × 43/64"
1	Slide valve	CRS rod	1/8 × 39/64"
1	Connecting rod	CRS rod	5/32 × 5/"
1	Eccentric rod	CRS rod	9/32 × 57/64"
2	Wrist pins	CRS rod	1/16 × 11/64"
1	Crankpin	CRS rod	1/16 × 9/64"
1	Crankshaft	CRS rod	3/8 × 15/16"
1	Eccentric	CRS rod	1/4 × 3/16"
1	Flywheel	CRS rod	3/4"dia. × 3/16"
1	Cylinder Head	brass rod	7/16" dia. × 1/8"
1	Blowpipe	aluminum rod	3/8 × 1"
2	Cap screws		0-80 × 1/4"
3	Cap screws		0-80 × 3/16"
2	Setscrews		0-80 × 1/16"



Fire Eater Engine





1

One of the amazing features of this very intriguing engine is that its energy source is merely a clean burning denatured alcohol flame positioned near the cylinder porthole. This is not a Stirling cycle motor; it's usually referred to as a "flame sucker." An even more accurate title would be "atmospheric" or "vacuum" engine. This little mechanism is not powerful, yet when properly adjusted it will attain speeds up to 1,100 rpm (Photo 1).

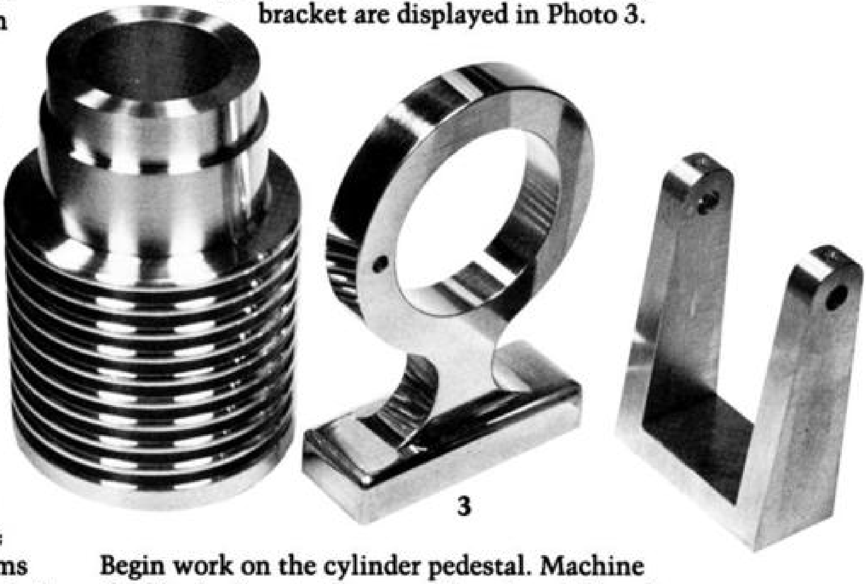
Even though it emits a smart, crackling "pop" like a gasoline motor, the similarity ends there. For instance, the power stroke of this engine occurs when the ringless piston moves toward the cylinder head. As the piston approaches the end of this stroke, a fast-acting slide valve opens the cylinder porthole. When the piston begins its outward stroke, the flame is sucked into the cylinder. Near the end of this stroke, the slide valve quickly closes the porthole. In a small fraction of a second, hot gases trapped in the cylinder begin to cool, thus creating a vacuum within the cylinder. Outside atmospheric pressure now pushes the piston inwards with enough force to keep the engine in motion until the entire cycle is repeated in the next revolution. The motor speed is controlled by the proximity and size of the flame near the porthole. Although this is a very simple engine with a minimum amount of parts, you'll find it to be a fascinating and challenging project, well worth the effort.

2

Our little motor has a 1" bore by a 1-3/4" stroke and is about as modern as an ancient design can get. It boasts an adjustable cam for fine tuning and a semi-balanced crank arm for optimum performance (Photo 2).

One inherent problem with this type engine is proper lubrication for the cylinder and piston. Oil, of course, would be the answer for an internal combustion motor, but our little contrivance is weak. Believe it or not, oil on the piston causes excessive drag; heat in the cylinder soon gums the oil and the engine will grind to a halt. I find that the lubricating problem can be overcome by occasionally coating the cylinder walls with fine graphite powder. Because of its free machining ability, stock aluminum was chosen for all the major parts, including the flywheel. If you prefer a steel flywheel, its weight would have to be reduced by narrowing the rim width and thickness approximately fifty percent. The cylinder could also be of steel or bronze. If the cylinder is made from aluminum, it's not advisable to have an aluminum piston. A bronze, cast iron, or steel piston is preferable – less chance of scoring.

The partially completed cylinder, the cylinder pedestal, and the crankshaft bearing bracket are displayed in Photo 3.



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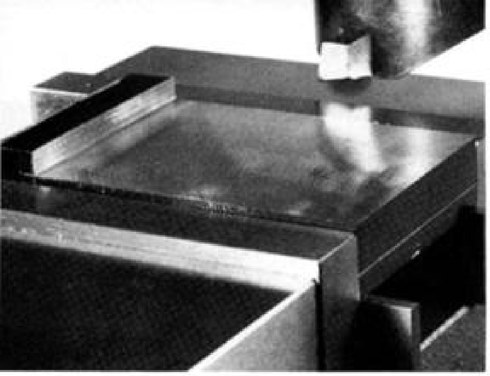
Begin work on the cylinder pedestal. Machine the blank piece to the proper length, width and thickness, being careful to render the base end of the piece as square as possible. Proceed by



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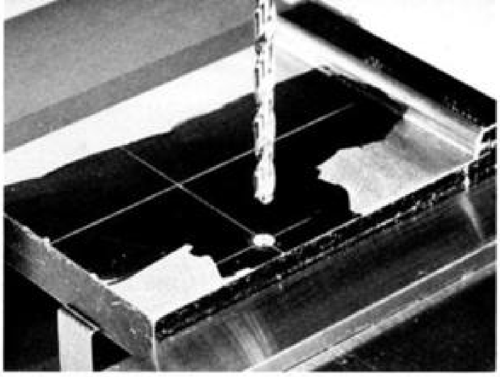

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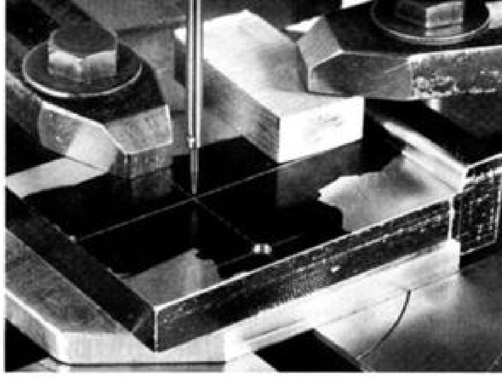

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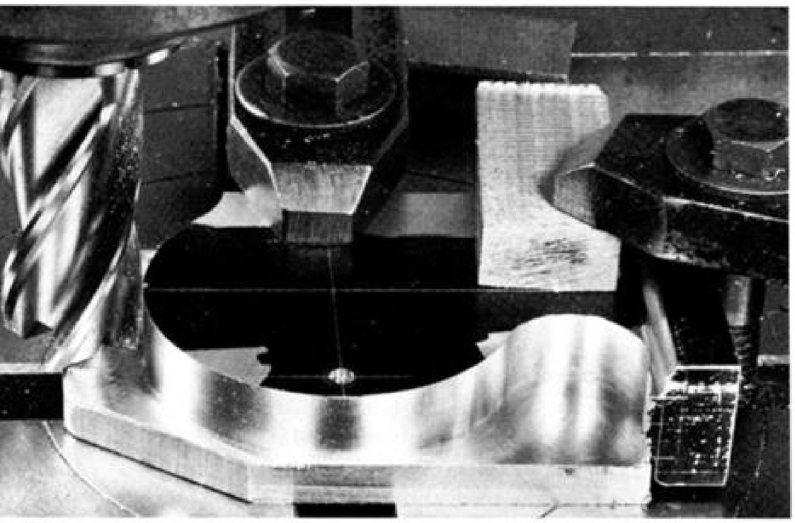

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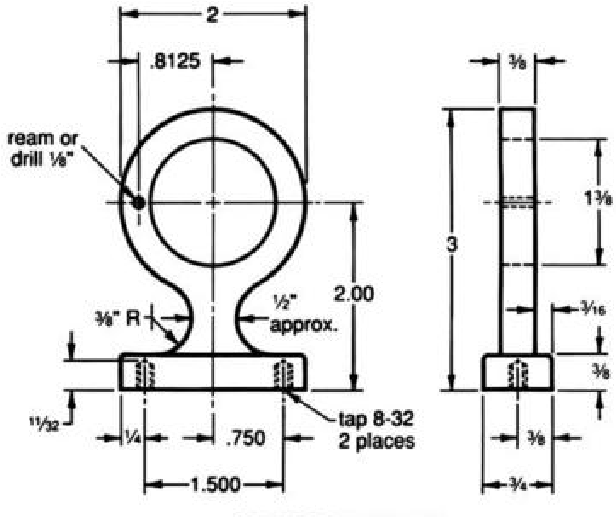
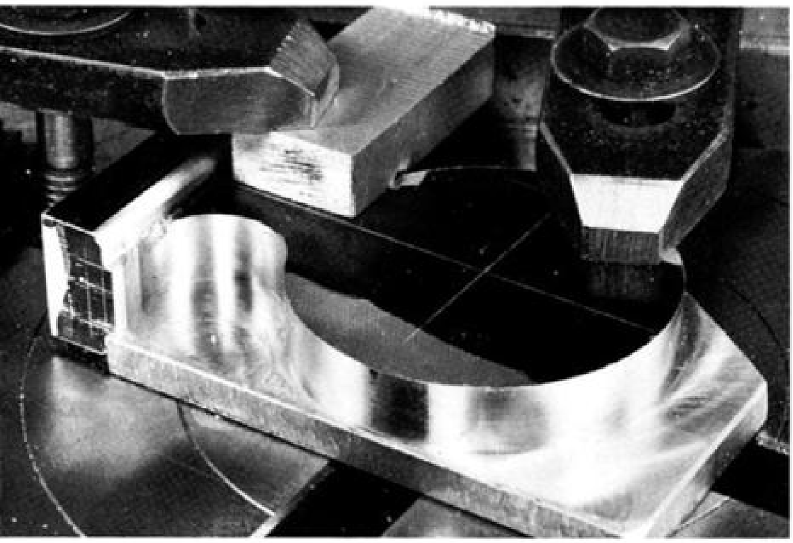


CYLINDER PEDESTAL
aluminum or steel
1 required



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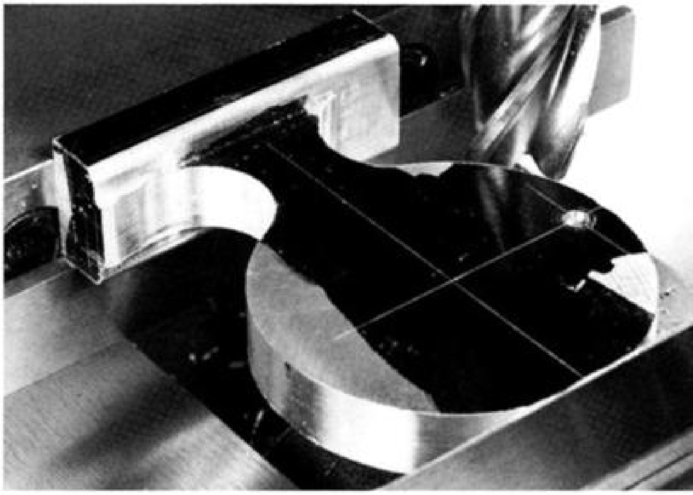

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accurately laying out center lines on the base end of the pedestal for the two threaded blind holes; use the mill to precisely drill and tap them. Follow by step-cutting each side of the plate down to form the beginning of what will be the foot of the unit (Photo 4). Now scribe center lines for the cylinder hole and the 1/8" push rod hole, but drill or ream only the 1/8" hole at this time (Photo 5).

The next operation is to form the contour of the pedestal (Photo 6). First, adjust the center line of your mill spindle to the true center of your rotary table. Lock the longitudinal table travel. Position the work on a sacrifice piece of flat scrap metal. Adjust the position of the blank by hand until its center lines are true to the mill spindle. Then clamp the piece tight. Note that both hold-down clamps are placed on one side of the work, thus allowing free space to contour one-half of the unit (Photo 7).

Use a 3/4" end mill; position it not only in front of the work but also about 1/32" below the work so the cutter will actually mill into the sacrifice piece of metal supporting the whole unit. Use the cross slide to gradually advance the cutter into the work. Stop machining when all flat spots around the side and top end of the blank have barely disappeared. Write down the reading on the calibrated collar of the cross slide; you'll need it later on.

The next step is to transfer the two hold-down clamps to the opposite side of the work without disturbing its position (Photo 8). Remove one clamp and secure it tightly to the opposite side; then place the second clamp in its new location. Now mill the remaining section of the contour.

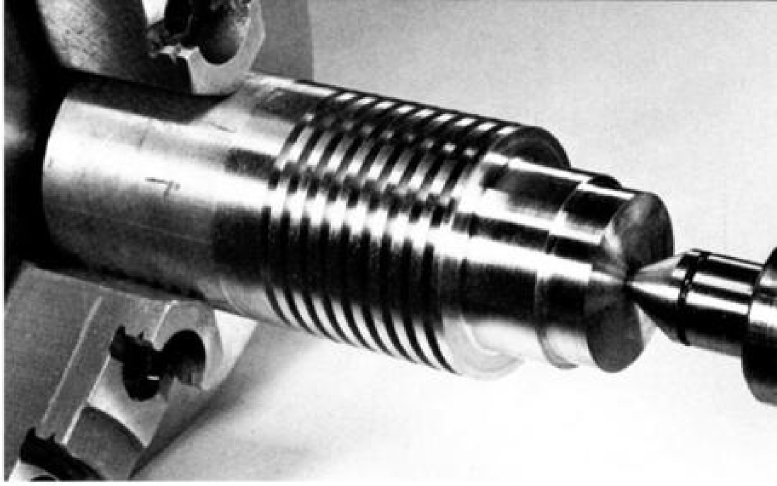
Transfer the work to the mill vise and carefully smooth out both little ridges that remain on the foot section (Photo 9).

The cylinder hole in the pedestal can be bored either in the mill or lathe. Just make certain the face of the pedestal is running true and is centered properly. Do not overtighten the chuck jaws if you use the lathe. After boring the hole to size, remove the work and smooth all sharp edges on the pedestal; follow by polishing it.

The cylinder is next (Photo 10). Machine down the outer end of the piece as shown, but leave the outer step diameter about .010" oversize for now (this is the section that will be pressed into the cylinder pedestal).

A 3/32" wide cutoff tool is used to form the fin slots, so set the compound slide parallel to the work and use its calibrated collar to accurately space the fins. Proceed by drilling and boring the blind cylinder hole. When nearing the correct diameter, check for taper. The finished bore should be as smooth as possible. Now prepare to finish machine the outer end step section for a .0002" press fit into the pedestal. Use a rather narrow and pointed tool bit. Hone a small radius on its cutting tip. Employ a fine carriage travel and apply aluminum cutting fluid during this operation (charcoal lighter fluid or sulfur base cutting oil will do in a pinch). When approximately .001" over the correct diameter, run the tool back and forth at the same setting to ensure that it has stopped cutting. Then very slightly advance the tool to machine off a few tenths of a thousand at a time until the desired size is reached.

Suppose (heaven forbid!) that we've goofed and this section is now undersize. That means



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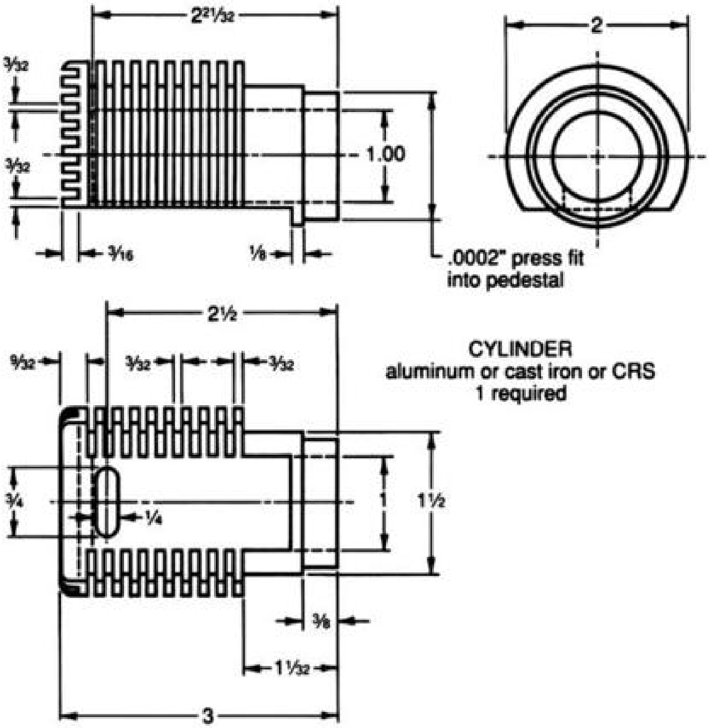
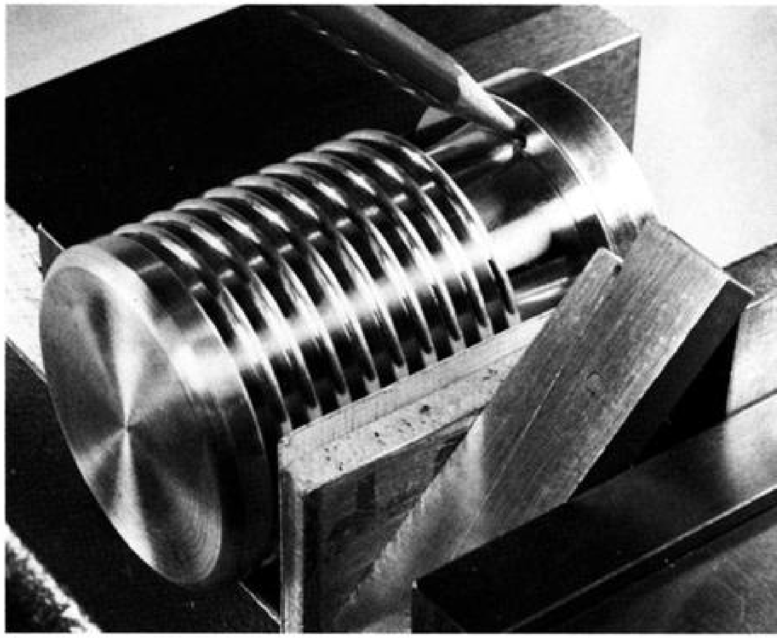


CYLINDER
aluminum or cast iron or CRS
1 required



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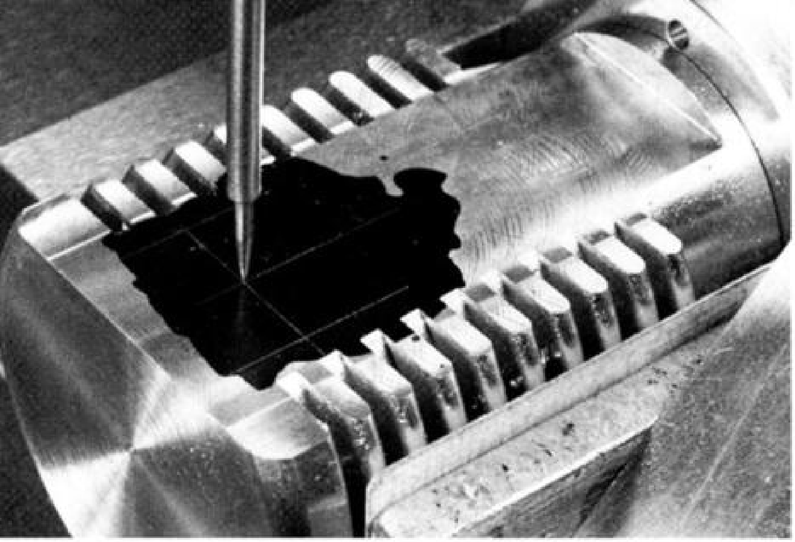

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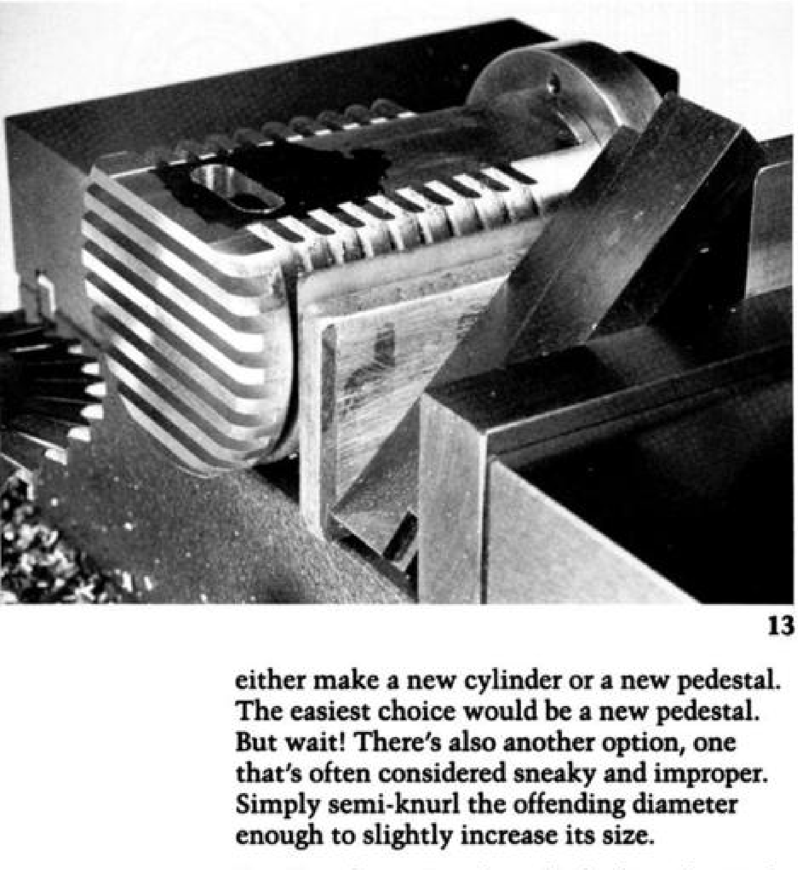

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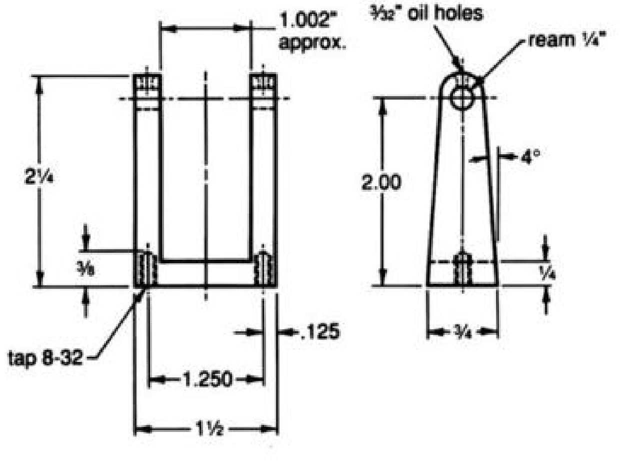
either make a new cylinder or a new pedestal. The easiest choice would be a new pedestal. But wait! There's also another option, one that's often considered sneaky and improper. Simply semi-knurl the offending diameter enough to slightly increase its size.

Continue by parting the cylinder from the stock, leaving excess metal to face off the head end.

Before pressing the cylinder into its pedestal, please examine Photo 11. It shows the cylinder after the pedestal is attached. Be certain the valve push rod hole in the pedestal is on the correct side of the cylinder before pressing the parts together. Then clamp the unit in a vise for machining the large flat on the cylinder side. Extend the head end of the cylinder to clear the side of the vise. Wedge an adjustable parallel in the vise to equalize vise pressure on the cylinder and pedestal foot. After milling the flat area, scribe center lines for the porthole. This can be done right in the vise without disturbing the setup (Photo 12). Bring the mill spindle over the slot center line. A 1/4" end mill is used to form the 3/4" long opening. Continue by milling the fins on the cylinder head with a 3/32" slitting saw (Photo 13). Start from the top and work down. This completes the cylinder, except for smoothing it up.

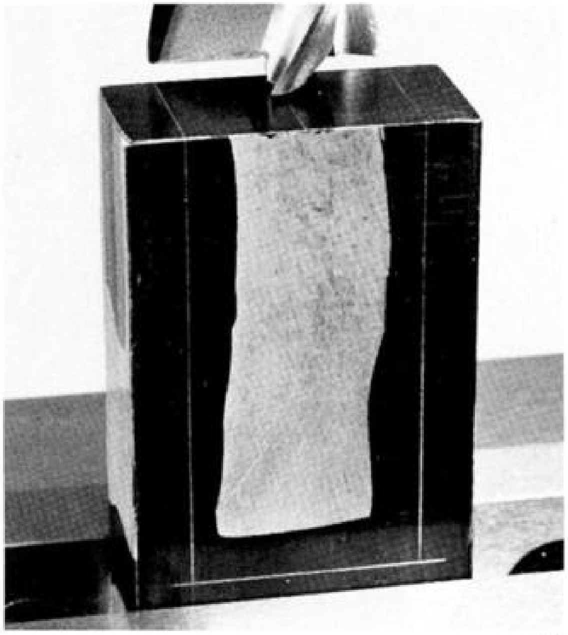
Next on the agenda is the crankshaft bearing bracket. There are several methods for removing the excess metal in the middle of the aluminum block. If a 1" end mill is available, the flywheel slot could be gradually milled downwards (Photo 14). In this case, the blank stock piece would have to be at least 1/4" longer than needed to give the vise sufficient gripping surface to hold the work securely – very dangerous otherwise!



CRANKSHAFT BEARING BRACKET
aluminum
1 required

A smoother job can be accomplished by positioning the blank on parallels as shown in Photo 15. Allow the piece to extend outward from the side of the vise a reasonable distance. Thus, later on, the thickness of each bracket arm can easily be measured with a micrometer. Now position a 5/16" end mill – or one no longer than 3/8" – about 1/64" away from the scribed layout line. The purpose is to gradually rough out a slot along the guide line to the intersecting line near the base end. After this slot is cut through the piece, move the end mill over to the other parallel line, staying away from it about 1/64". Mill the second slot through. Then mill through what's left of the surplus metal close to the intersecting line near the base.

The space between the two bracket arms must now be widened to 1.002" (approximately). First, mike the outside width of the bracket.



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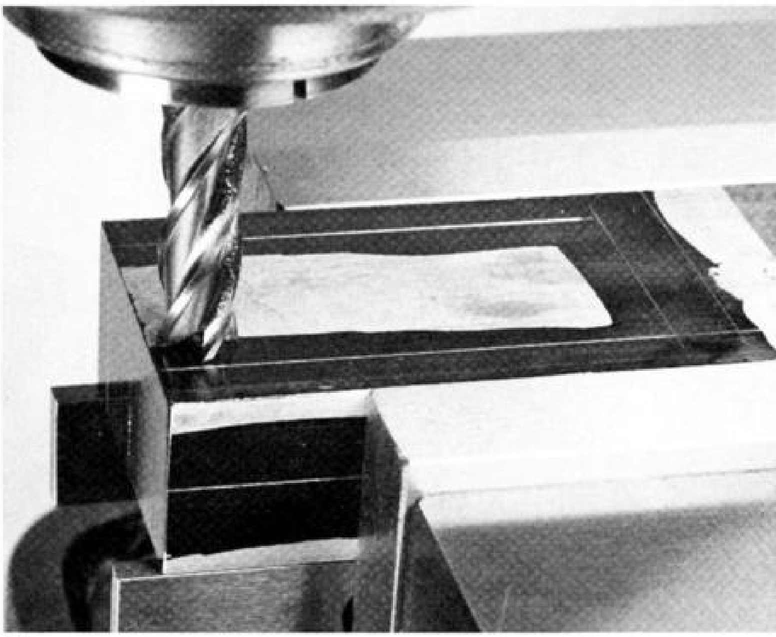

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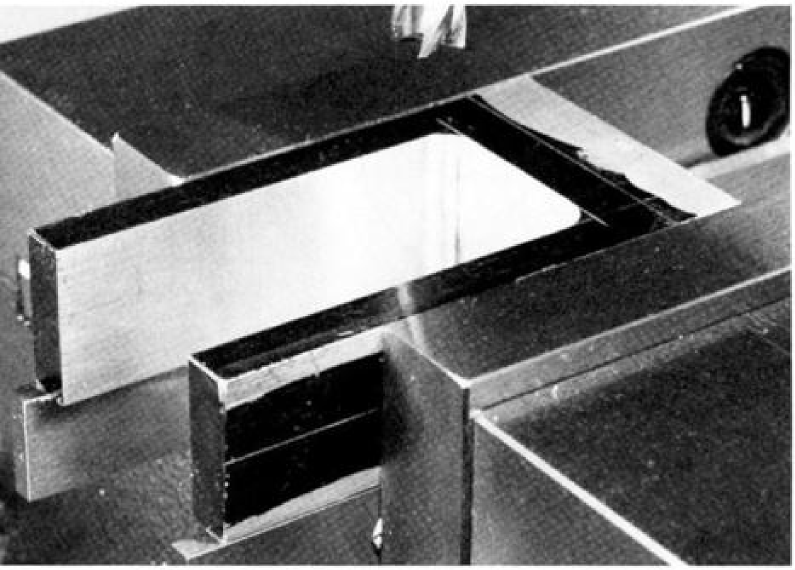

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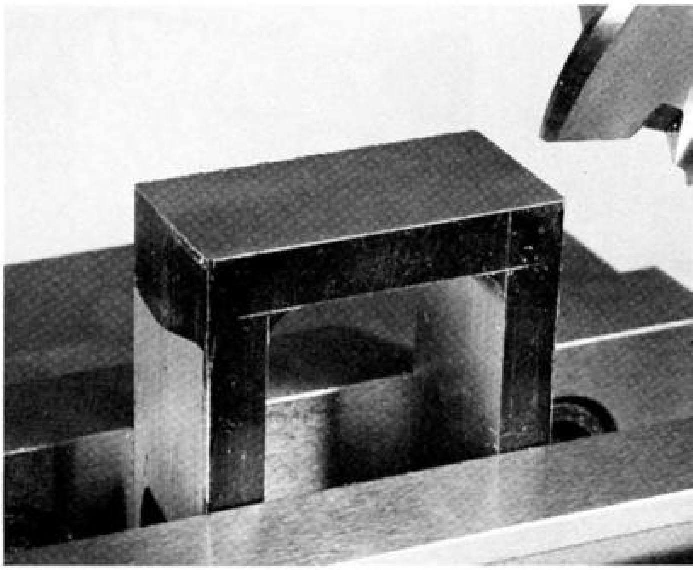

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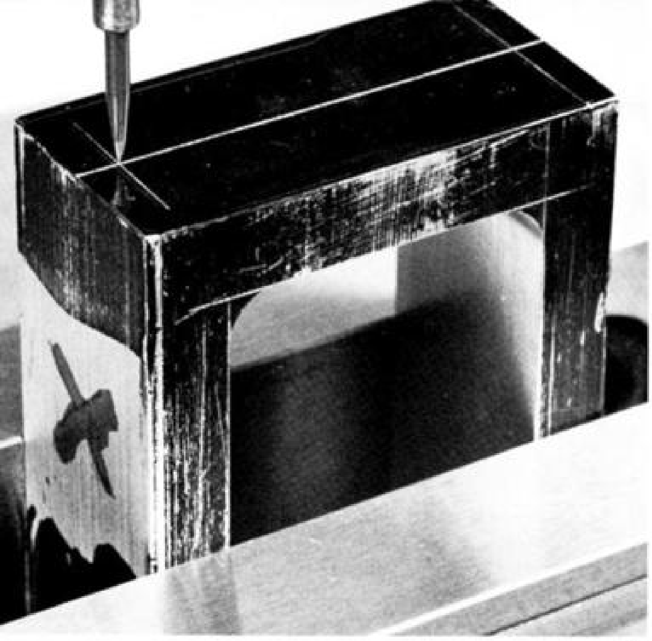
Subtract 1.002" from that reading. The result is divided by 2. The answer will be the final thickness for each arm of the bracket. Photo 16 shows the completed milling for this section of the bracket. Continue by accurately squaring off the base end of the bracket (Photo 17). Prepare to scribe accurate center lines for the two blind threaded bolt holes in the base (Photo 18). Make some type of identifying mark on one side of the bracket. Scribe the cross line for the first bolt hole exactly .125" from that side. On assembly, that side of the bracket should be positioned facing towards the connecting rod crank arm.

The center line for the crankshaft bearing holes must be placed precisely 2.00" from the base. If your scribed lines are accurate, use a wiggler to locate them; otherwise, use an edge finder (Photo 19). Next, machine the 4" taper on the bracket arms with the aid of an angle vise (Photo 20).

Although the flywheel is easily machined from aluminum (Photo 21), care must be taken to drill and ream a true running shaft hole. Be gentle with the center drill when spotting location for the hole and never allow the drill to bang into the work. After machining the first side of the flywheel, reverse it in a four-jaw chuck, allowing enough of the finished perimeter of the flywheel to be exposed for trueing up with a dial indicator. After completion of the lathe work, the optional spoke holes can be



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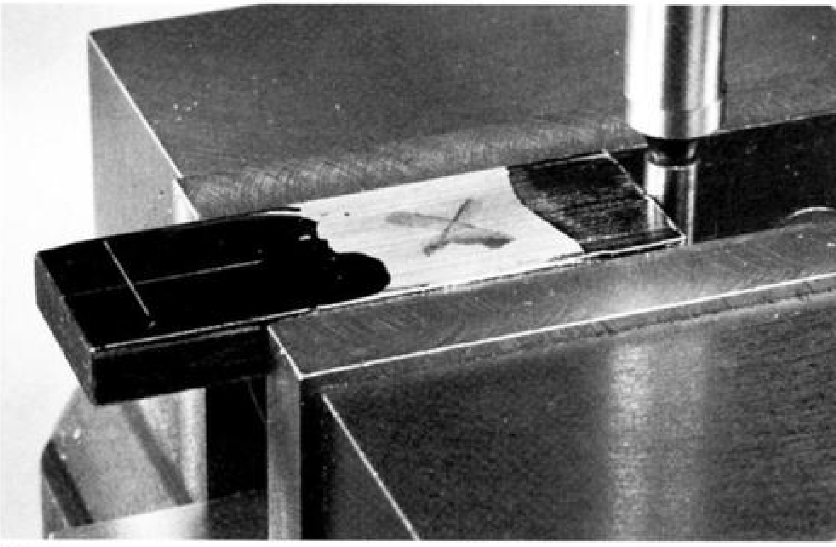

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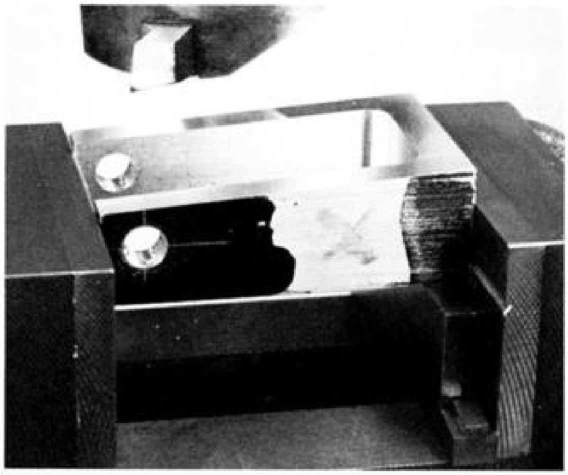

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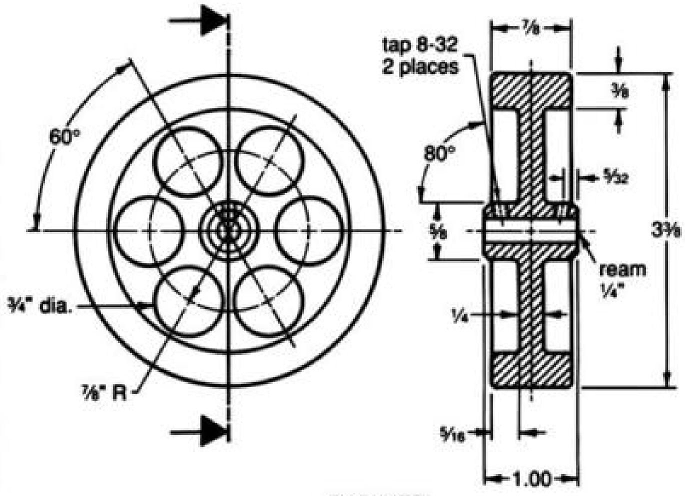
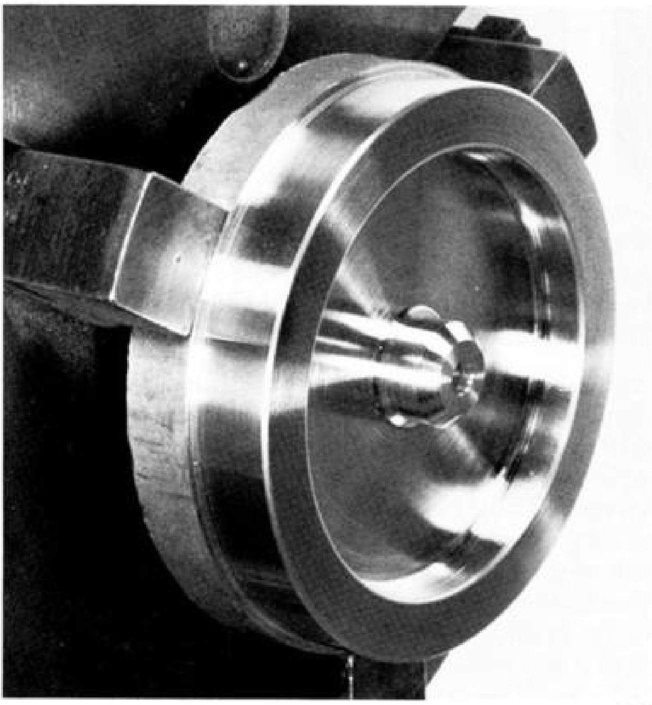


FLYWHEEL
aluminum
1 required



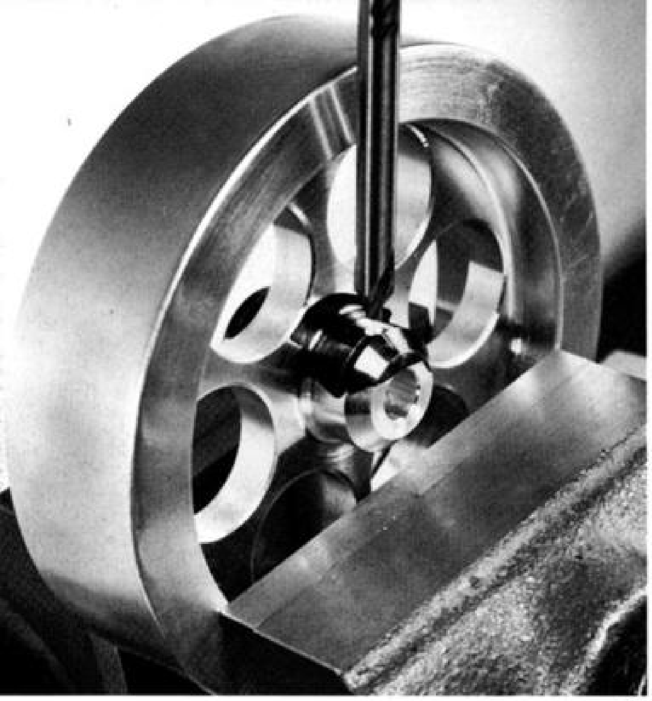
21

drilled through the flywheel. An easy method is to center the work on the mill rotary table. Elevate the flywheel on parallels to avoid drilling surplus holes in the rotary.

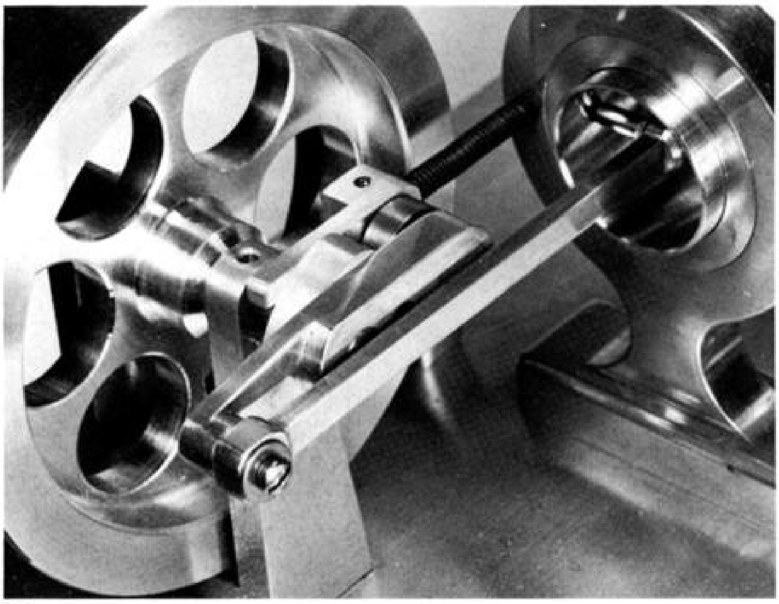
The location for the setscrew holes in the flywheel hub are spot drilled with a long center drill. The work is tilted about 10° (Photo 22). It's prudent to complete all of the engine parts before mounting anything to the baseplate. Please examine Photo 23; it illustrates how the crankshaft parts will appear after assembly.

Begin work on the piston and connecting rod units (Photo 24). Visible are the bronze piston, aluminum connecting rod, tubular wrist pin, and the wrist pin yoke. The nut secures the piston to the wrist pin yoke.

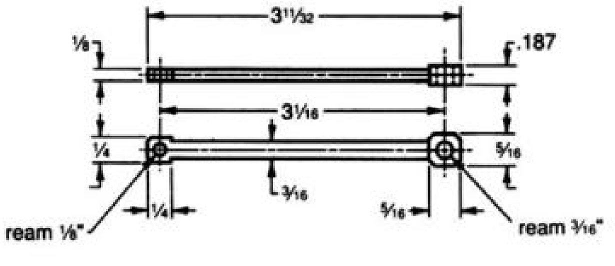
The piston needs very little explanation except to mention that it's advisable to rough out the OD of the piston first, leaving it about .010"



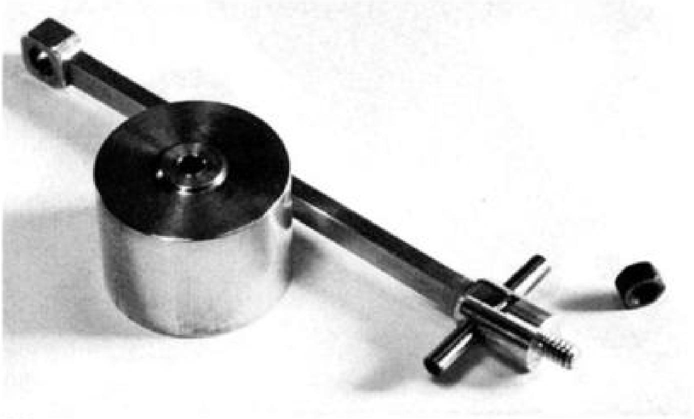
22



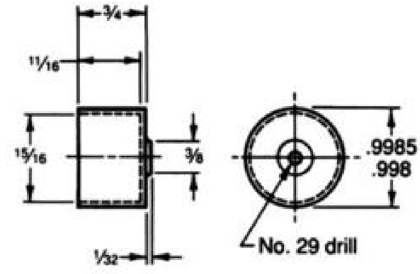
23


3 11/32
1/8
.187
3 1/16
1/4
5/16
3/16
1/4
5/16
ream 1/8"
ream 3/16"

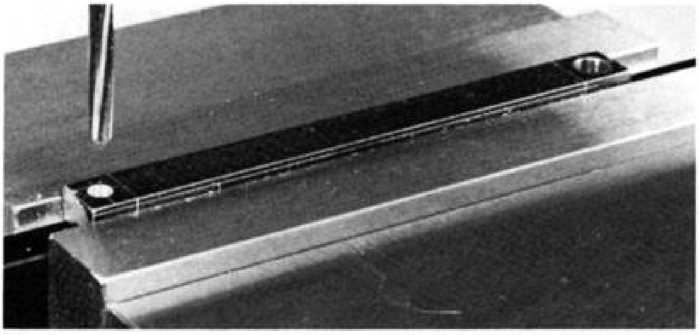
CONNECTING ROD
aluminum
1 required



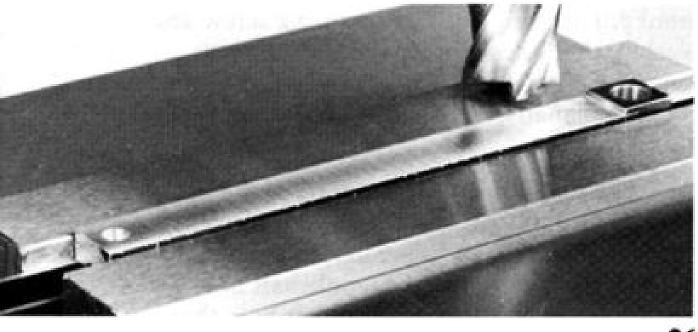
24


3/4
11/16
15/16
3/8
.9985
.998
No. 29 drill
1/32

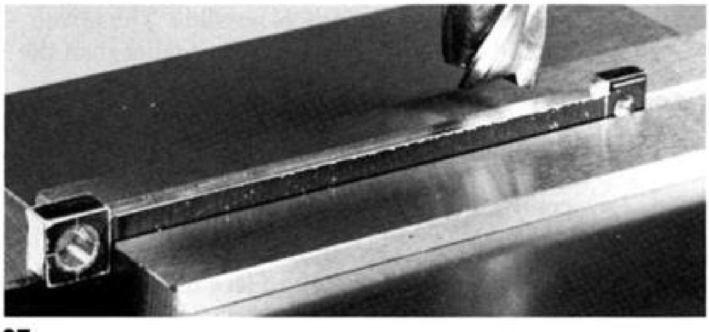
PISTON
bronze, cast iron or CRS
1 required



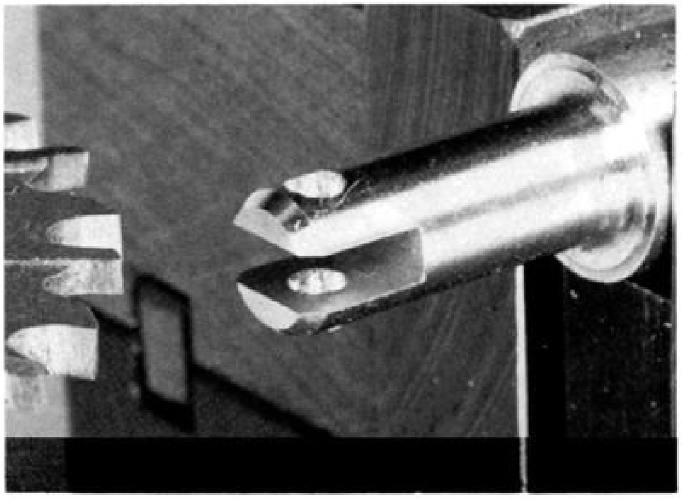
25



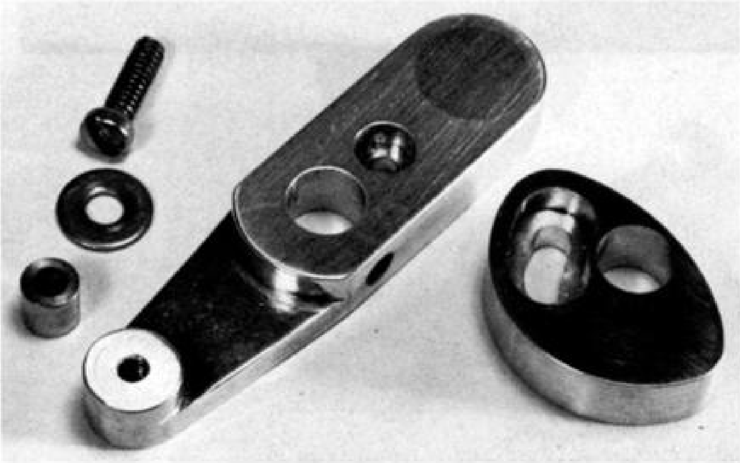
26



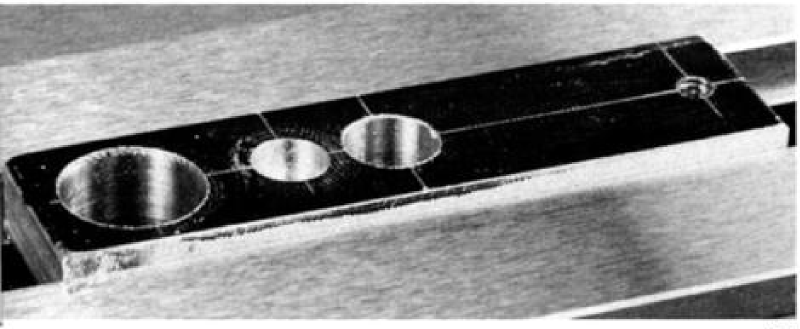
27



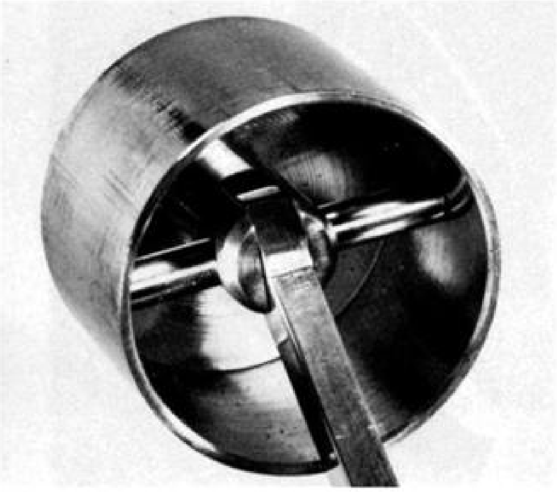
28



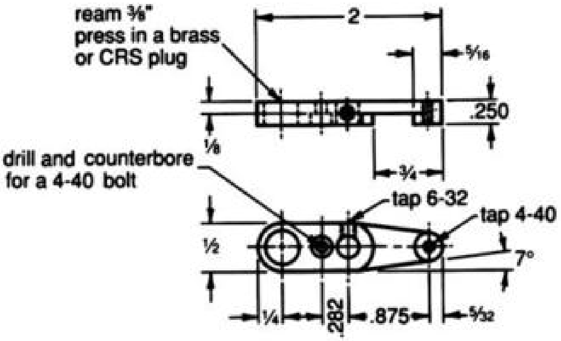
30



31



29



CRANK ARM
aluminum
1 required

oversize. Then drill and bore the ID to size. Now return to the OD and carefully finish it, rendering it as smooth as possible. The piston should be from .0015" to .002" smaller than the cylinder bore; any larger than that seems to add to the problem of scoring in the cylinder. More than .002" clearance means excessive piston leakage, resulting in a hard starting, pepless motor.

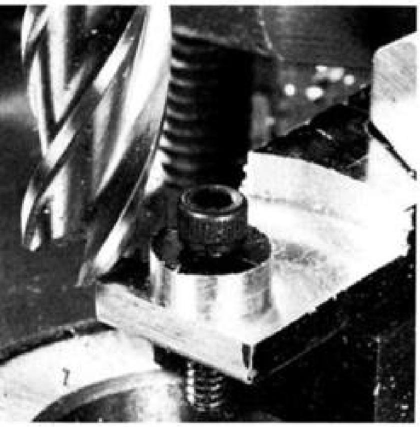
The piston is now cut from the stock piece, allowing enough length to face off the head end. The piston should be gripped very gently in a three-jaw chuck for this operation. If a 1" collet is available, use that instead, but don't overtighten it on the work.

Machine the connecting rod blank to the proper overall length, width, and thickness. Lay out center lines for the wrist pin and crankpin holes, then drill and ream them to size (Photo 25). Continue by step-cutting each side of the arm (Photo 27). Remove the work, and by hand, round off any sharp edges on the con-rod.

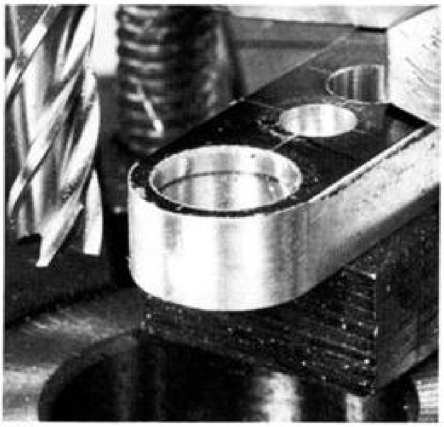
Photo 28 shows how the wrist pin yoke was slotted, and in Photo 29 is a view of the assembled unit.

Visible from the left in Photo 30 are the steel crankpin bushing with its retaining screw and washer, then the semi-balanced crank arm (note the circular brass weight plugged into one end). Finally, at the right, is the fast-acting aluminum cam.

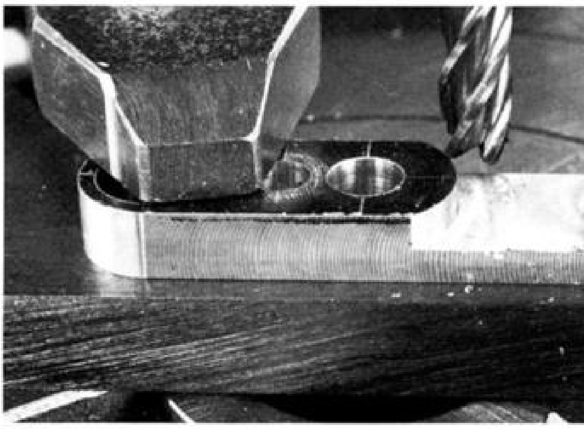
Photo 31 illustrates the beginning of the crank arm. Near the right-hand end of the blank is the threaded hole for the crankpin bushing. Next to that is the reamed crankshaft hole. Then follows the countersunk bolt hole that



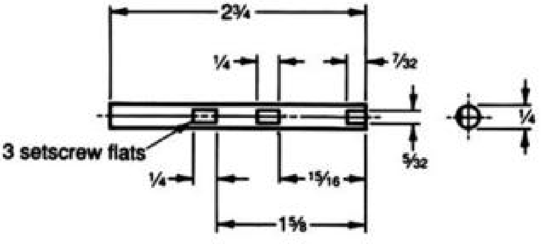
32



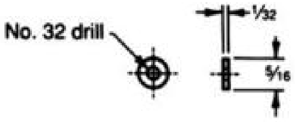
33



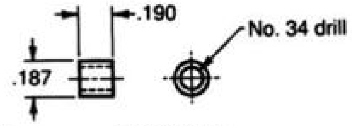
34



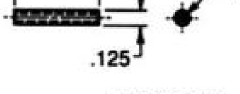
CRANKSHAFT
CRS
1 required



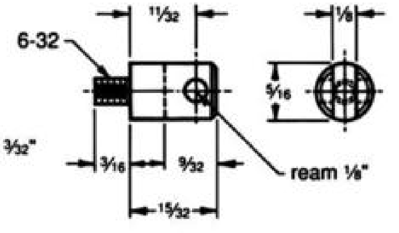
CRANKPIN RETAINER WASHER
CRS
1 required



CRANKPIN
CRS
1 required



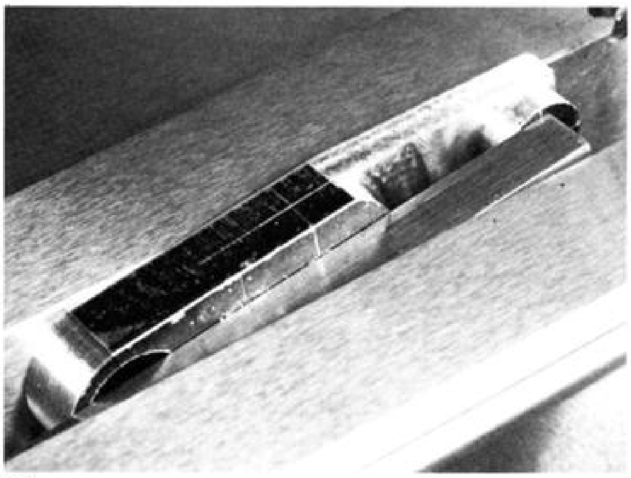
WRIST PIN
drill rod or CRS
1 required



WRIST PIN YOKE
aluminum
1 required

will secure the cam to the crank arm. Last is the 3/8" reamed hole for the press fitted brass (or steel) counterbalance weight.

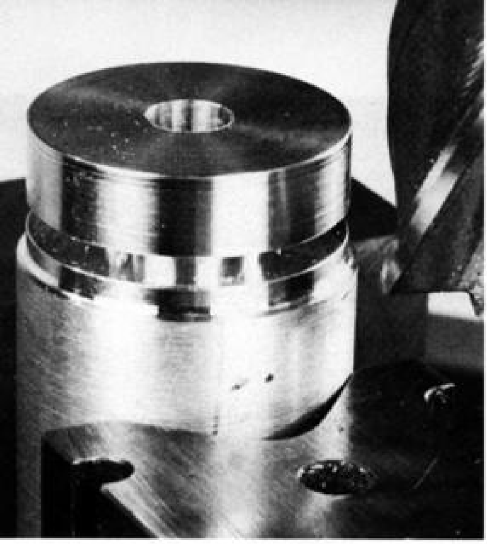
In Photo 32, a portion of the crankpin end of the arm is being rounded with the aid of the rotary table. A circular headed bolt was inserted in the arm as a means of centering the work. Run the indicater around the bolt head. Follow by rounding the opposite end of the arm (Photo 33). Then continue by rounding the step shoulder adjacent to the crankshaft hole (Photo 34). Finally, mill the taper on the crank arm (Photo 35).



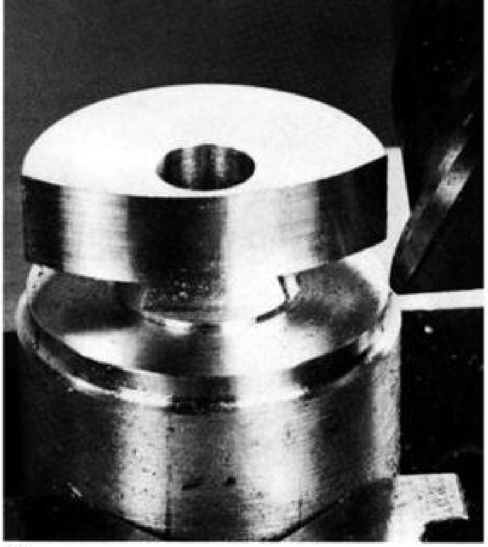
35

Begin work on the Cam by turning the stock piece to the proper diameter. Drill and ream the shaft hole about 3/8" deep. Mount a cutoff tool in the lathe as if to part the disk at its proper thickness (.250"). However, merely run the cutter into the work about 1/4" deep, leaving the disk still attached to the stock. Now transfer the work to the mill and rotary table.

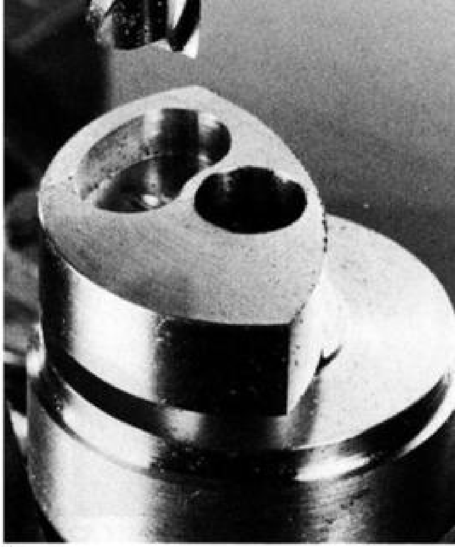
First, center the rotary true to the mill spindle. Then set the mill longitudinal table calibrated collar to zero for a table movement later on, to the right. Now lock the table. Set the calibrated collar on the cross slide to zero, for a table movement away from you...of course, note the location of the cross slide, thus enabling you to bring it back to this exact position at will. Proceed to mount the work stock piece vertically in a small vise. Now move the cross slide from its zero setting exactly 9/16" away from you and lock it. Place the vise on the rotary table and, using a dial indicator in the spindle, shift the vise by hand until the work is centered true to the mill spindle. Then clamp



36



37

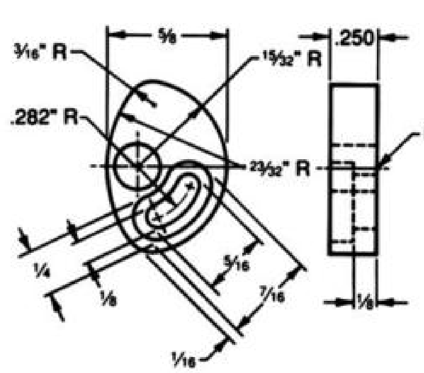


38

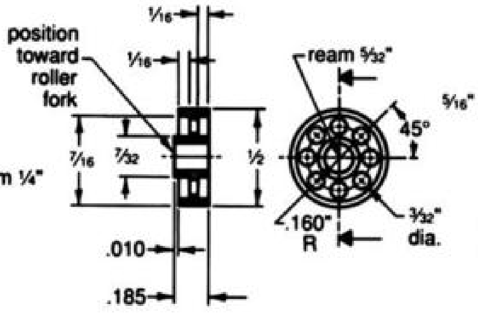
the vise securely to the rotary.

For better visibility, it's best to position the end mill in front of the work, so move the cross slide farther away from you, and install either a 1/2" or 3/8" end mill. Lower it enough to mill the 1/4" wide rim of the cam (Photo 36). With the cutter in motion, advance the cross slide towards you until the cutter makes contact with the work. Then gradually feed inwards, using the rotary crank to mill an arc on the cam. When the high point of the arc reaches about 1/16" from the rim of the cam center hole, begin measuring across the middle of the arc to the opposite rim of the cam. Stop milling when this reading reaches .625" (Photo 37).

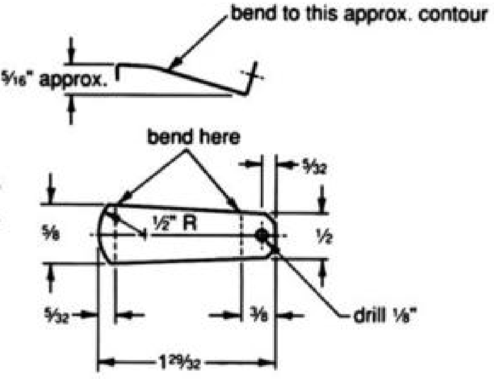
The next step is to mill the cam adjusting bolt


⅝
.250
3⁄16" R
15⁄32" R
.282" R
23⁄32" R
ream ¼"
¼
⅛
5⁄16
7⁄16
1⁄16
⅛

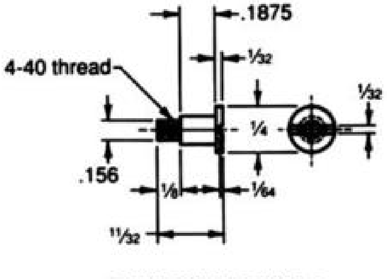
CAM
aluminum
1 required


1⁄16
position toward roller fork
1⁄16
7⁄16
7⁄32
½
.010
.185
ream 5⁄32"
45°
.160" R
3⁄32" dia.

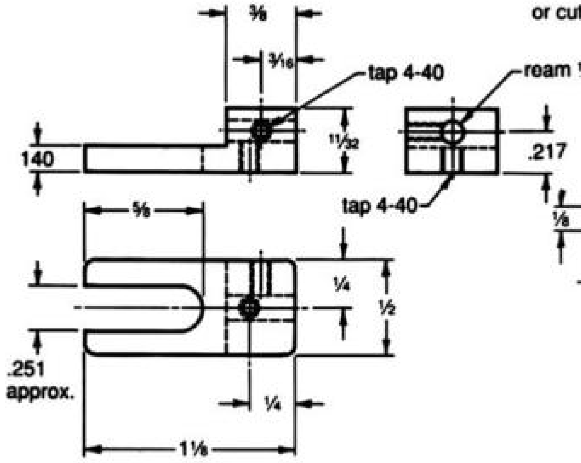
CAM ROLLER
CRS
1 required


bend to this approx. contour
5⁄16" approx.
bend here
5⁄32
⅝
½" R
½
5⁄32
⅜
drill ⅛"
129⁄32

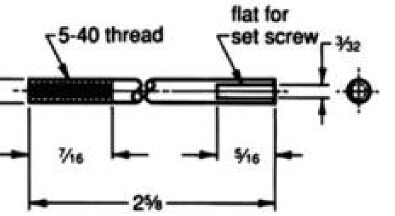
VALVE FLAT SPRING
.007" steel shim stock
or cut from .007" thick food "tin" can
1 required


.1875
4-40 thread
1⁄32
1⁄32
¼
.156
⅛
1⁄64
11⁄32

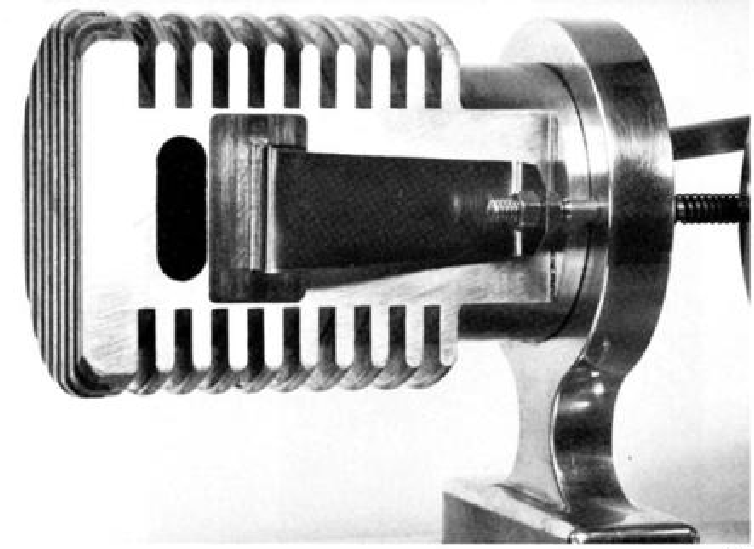
CAM ROLLER SHAFT
CRS
1 required


⅜
3⁄16
tap 4-40
ream ⅛"
140
11⁄32
.217
tap 4-40
⅝
¼
½
.251 approx.
¼
1⅛

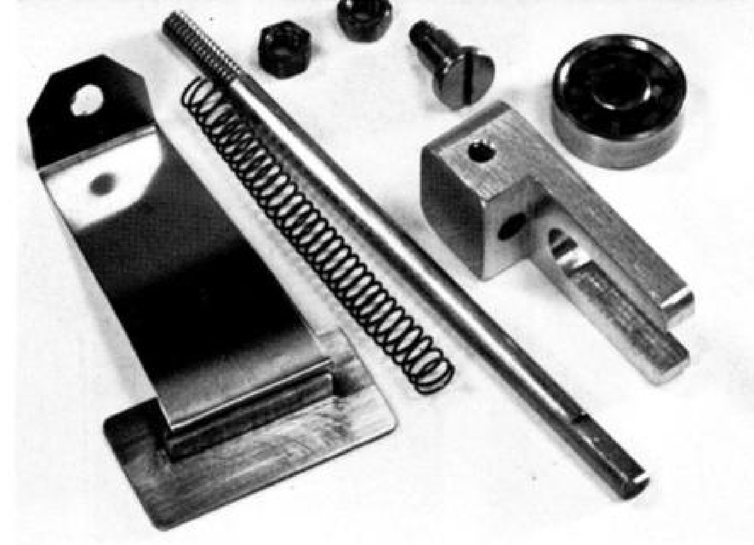
CAM ROLLER FORK
aluminum
1 required


5-40 thread
flat for set screw
3⁄32
⅛
7⁄16
5⁄16
2⅝

VALVE PUSH ROD
CRS or drill rod
1 required



39



40

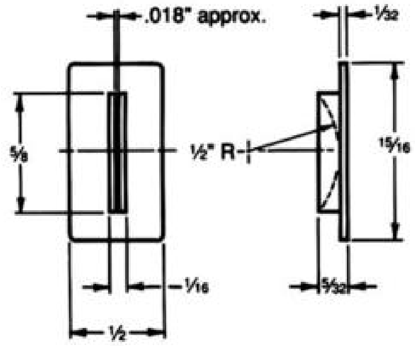
slot in the face of the cam; that means the work will have to be relocated true to the center of the rotary table. Return the mill cross slide back to its original zero setting and lock it. That should center the mill spindle with the center of the rotary. Install an indicator in the spindle. Loosen the clamps holding the vise and shift the vise by hand until the hole in the cam runs true to the spindle. Clamp down the vise, and install a 1/4" end mill. Unlock the longitudinal table travel, and move the table to the right .281" from its zero setting, then lock the table.

With the aid of the rotary crank, gradually mill out the curved slot to the proper depth (Photo 38). Then install a 1/8" end mill, and gradually cut a narrow slot all the way through the cam. Return to the lathe, and part the cam from its stock piece. The sharp tips on the cam lobes are rounded by hand or with a disk sander.

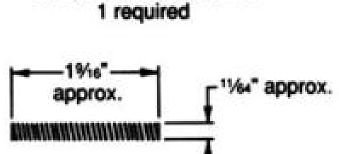
The elemental yet effective slide valve and flat spring are illustrated in Photo 39. Parts for the valve push rod assembly (minus one setscrew) are displayed in Photo 40. The flat spring on the left has its curved tip resting in a loose fitting shallow slot in the valve plate. Next are the compression spring and the push rod, followed by the cam roller fork and the roller wheel. Above the fork is the roller shaft.

The flat spring is cut from .007" steel shim stock or from the side of an ordinary food can that is also .007" thick – either will work. The three simple steps of forming the spring are shown in Photo 41.

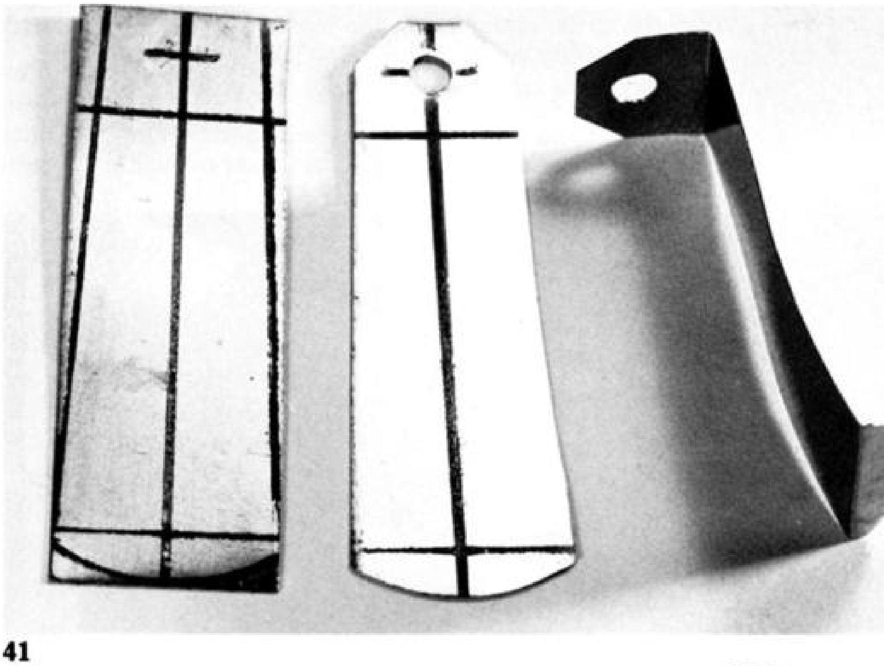
The slide valve can be machined from steel, cast iron, or bronze. The blank piece of metal to be used should be made 1/8" thicker than the finished product specifies. The extra thickness is for gripping in the vise during the machining process. Scribe layout lines on the



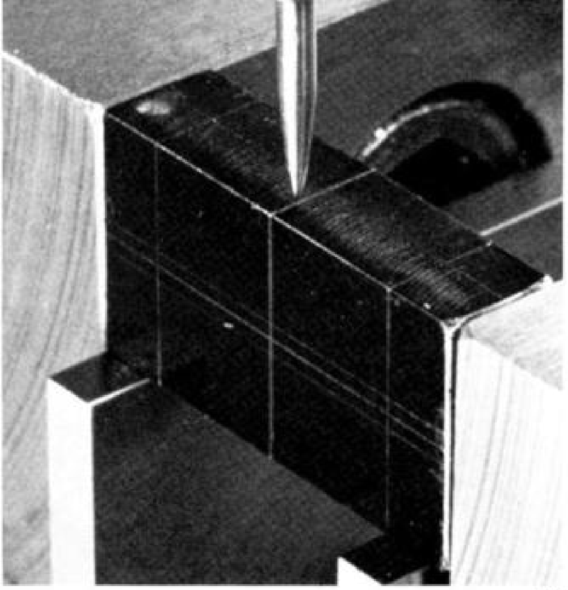
VALVE
CRS, cast iron or bronze
1 required



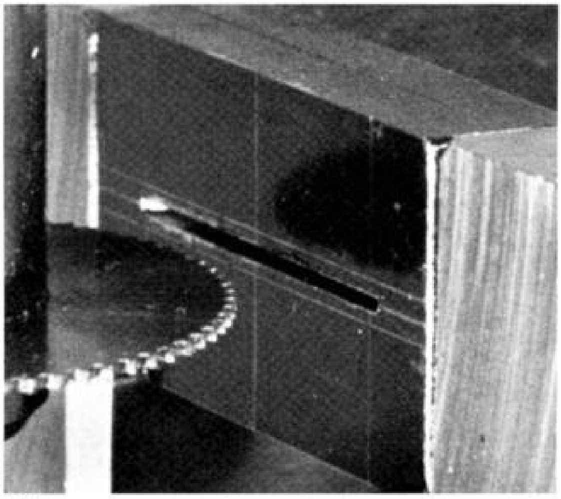
VALVE SPRING
32 turns of .015" dia. spring wire
1 required



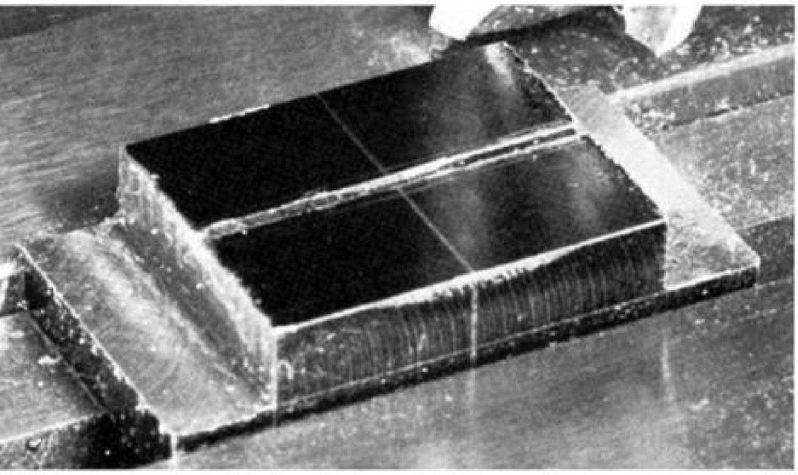
41



42



43



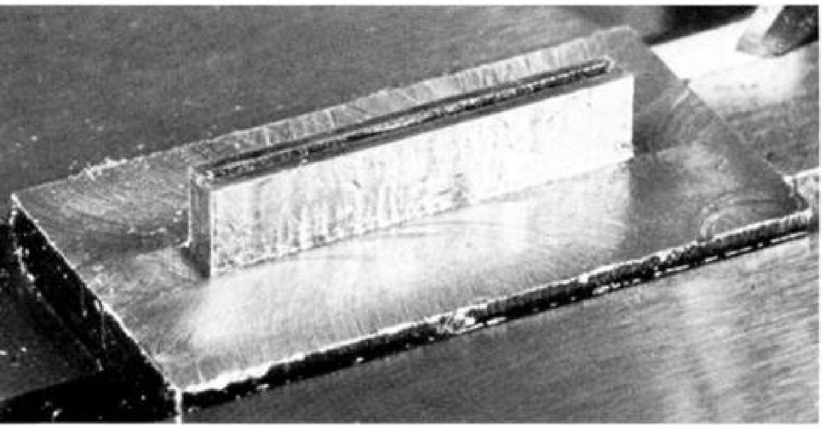
44

block and mount it in the mill vise (Photo 42). Set the mill spindle to the center line of the work. Install a 1" diameter by .018" jeweler's slotting saw to form the slot (Photo 43). Run the cutter straight into the work. (The saws are readily available from ENCO, 5000 West Bloomingdale Avenue, Chicago, Illinois 60639).

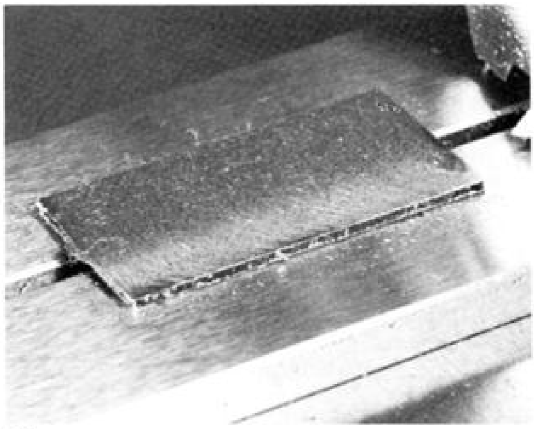
Proceed by positioning the work as shown in Photo 44. Step cut each end first, then gradually mill the sides to form the thin wall that runs parallel to the slit (Photo 45). Now turn the piece upside down in the vise, gripping it on the narrow wall section just machined. Gradually mill off the surplus metal (Photo 46). It's important that this surface is rendered as smooth as possible, so sand it on a flat surface. Begin sanding with medium fine grit emery paper, placed face up on the flat surface, until the tool marks disappear. Then use a finer grit paper and finally polish it on 600 grit paper. Be certain to smooth any sharp edges around the valve plate – otherwise they may dig into the aluminum surface of the cylinder when the engine is in motion.

The aluminum baseplate should be machined so its edges are square and parallel to each other. My piece of metal also had to be lightly machined on both sides to flatten it. The optional bevel around its edges was formed with a ball end mill.

It would be possible to eliminate the metal base entirely and mount the engine components directly to a hardwood base, providing it is perfectly flat.



45



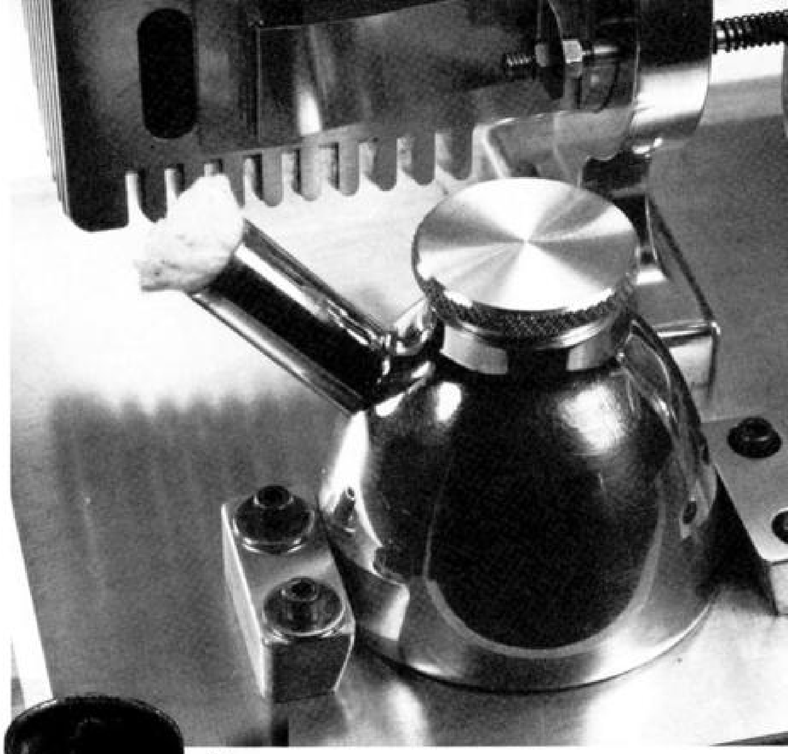
46

A suitable fuel tank is the next item to tackle (Photo 47). A small old-fashioned oil can makes an ideal tank – that is, providing you can find one! Well, I couldn't locate one in any of the stores, so ended up buying an ordinary keyless-type door knob that was easily converted into a tank. The one in the photo is from a Wedlock closet/hall door knob set, stock No. SV600, design – *Sunray*.

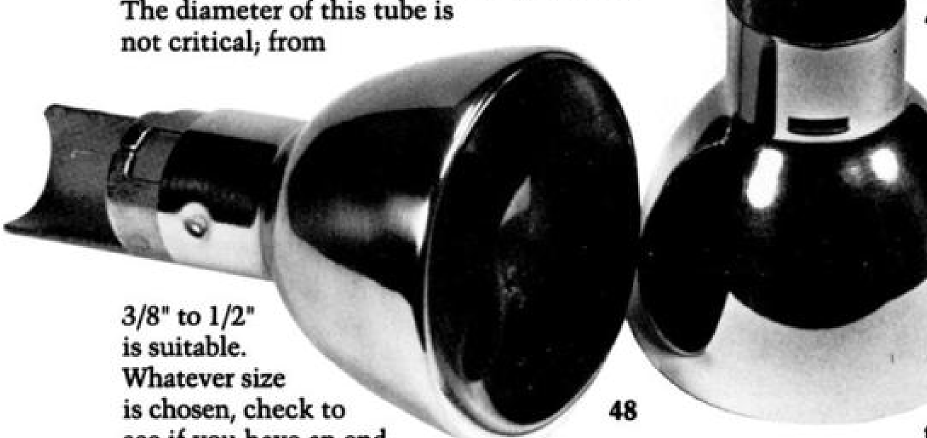
The two knobs from the set are shown in Photo 48. The one at the left is the easiest to work. Merely chuck in on the steel tubing sleeve and a small portion of the brass hub (Photo 49). Position the cutoff tool just to the right of the indentations in the brass hub. Feed in the cutoff tool very slowly so it won't grab onto the work. Cut only deep enough to part the brass from the steel inner sleeve.

Use an angle vise in the milling machine to drill the hole in the tank for the wick tube. The diameter of this tube is not critical; from 3/8" to 1/2" is suitable. Whatever size is chosen, check to see if you have an end mill the same diameter (within a few thousandths): it will be utilized to drill the hole in the tank. First, center drill the location for the spout hole (Photo 50). Then follow with the end mill, using a low spindle speed and a very gentle downward pressure to avoid the effects of chattering.

A simple fixture to hold the fuel tank in place on the engine base is shown in Photo 51. The clamp at the left has oversize bolt holes, thus allowing for some adjustment of the clamp when in place on the motor base. The holes of the second clamp are deeply counterbored; springs on the hold-down bolts allow the clamp to flex up and down slightly to exert a springy tension on the out-of-round tank.

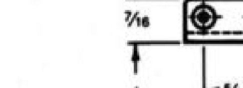


47

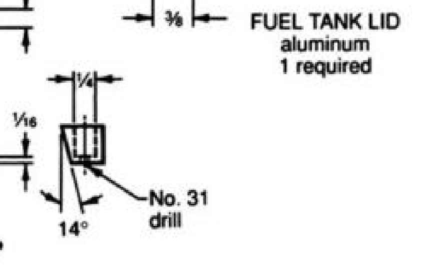


48

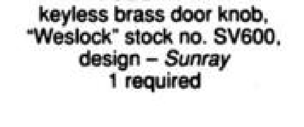
No explanation is necessary for making the remaining parts of the engine; there is nothing tricky at all in their construction.



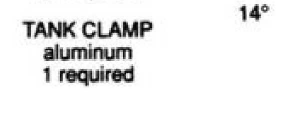
CLAMP SPRINGS
.025" dia. spring wire,
7 turns
2 required



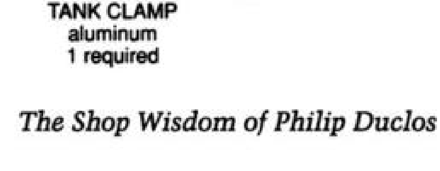
FUEL TANK LID
aluminum
1 required



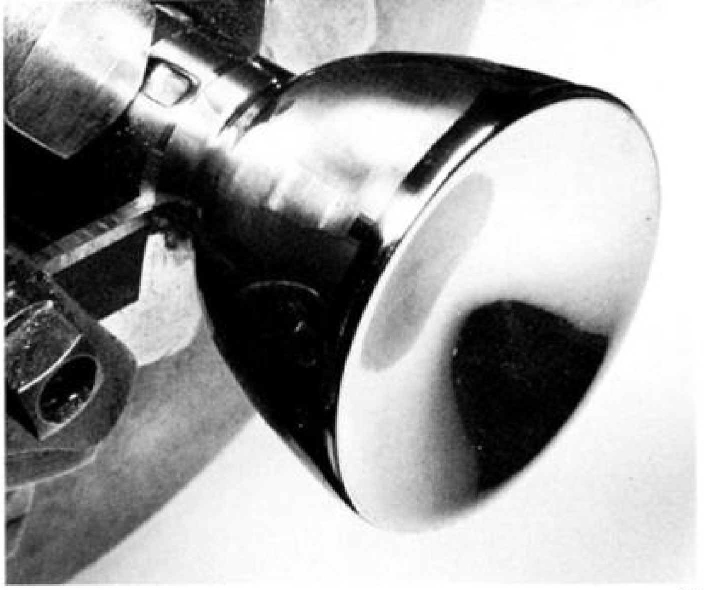
FUEL TANK
keyless brass door knob,
"Weslock" stock no. SV600,
design – *Sunray*
1 required



TANK CLAMP
aluminum
1 required

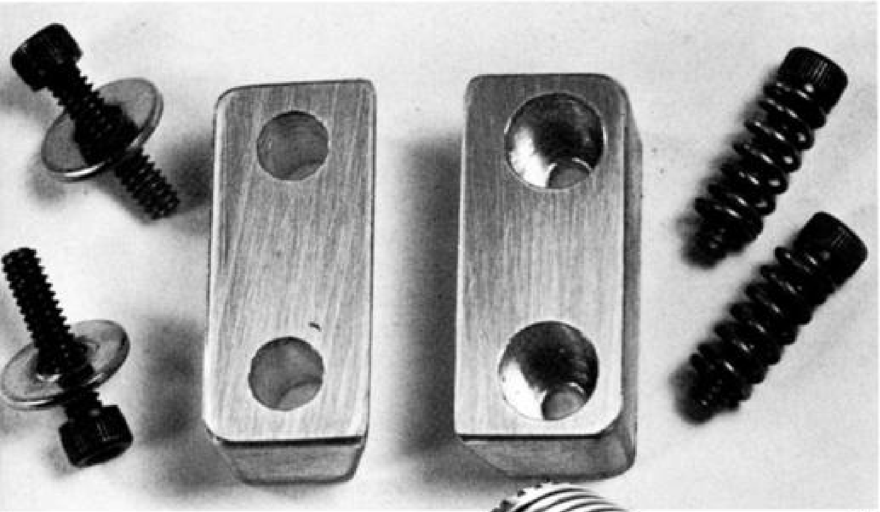


TANK CLAMP
aluminum
1 required



49

50

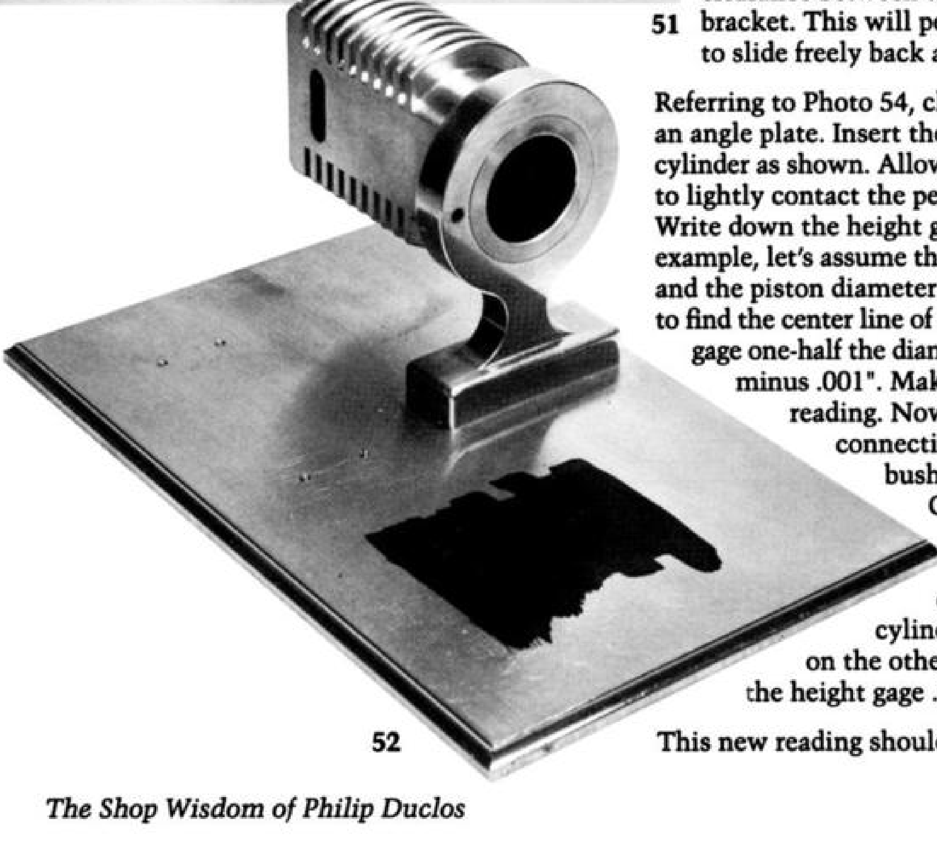


51

Upon completion of all the engine parts, accurately scribe center lines for the countersunk bolt holes that will secure the cylinder unit to the baseplate. Use the milling machine to precisely drill the holes, since they must line up perfectly with the threaded blind holes in the cylinder pedestal. Upon completion, bolt the cylinder unit to the base. Now apply layout bluing to the baseplate in the area where the crankshaft bearing bracket will be situated (Photo 52).

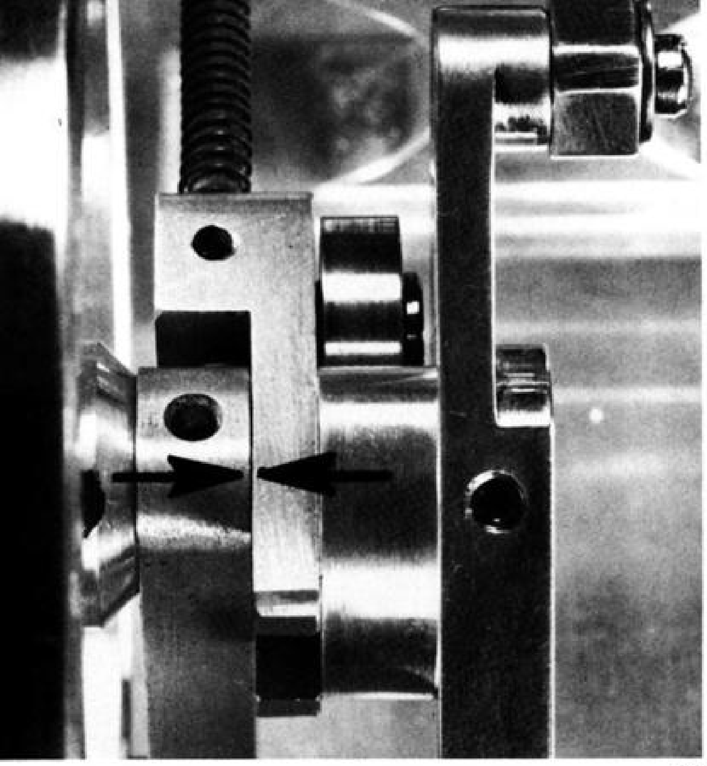
Please examine Photo 53. When attempting to locate the lateral position for the bracket, it's essential to allow about .003" clearance between the cam roller fork and bracket. This will permit the roller fork to slide freely back and forth.

Referring to Photo 54, clamp the baseplate to an angle plate. Insert the piston into the cylinder as shown. Allow the height gage scribe to lightly contact the perimeter of the piston. Write down the height gage reading. As an example, let's assume the cylinder bore is 1.00", and the piston diameter is .998". Therefore, to find the center line of the cylinder, lower the gage one-half the diameter of the piston – minus .001". Make a note of this reading. Now, let's assume the connecting rod crankpin bushing is .190" in length. One-half of that length should be positioned on one side of the center line of the cylinder and the other half on the other side. So now lower the height gage .095".

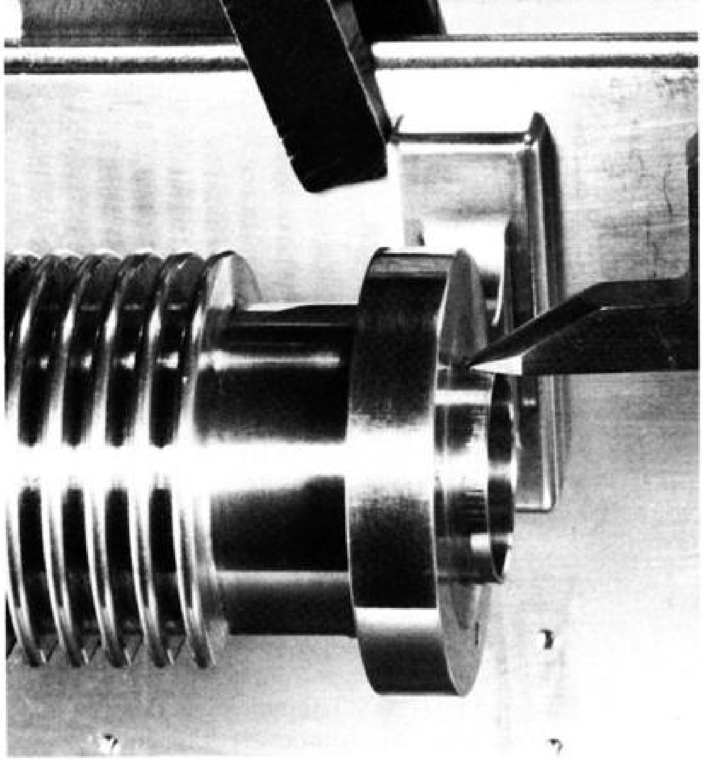


52

This new reading should place the scribe point



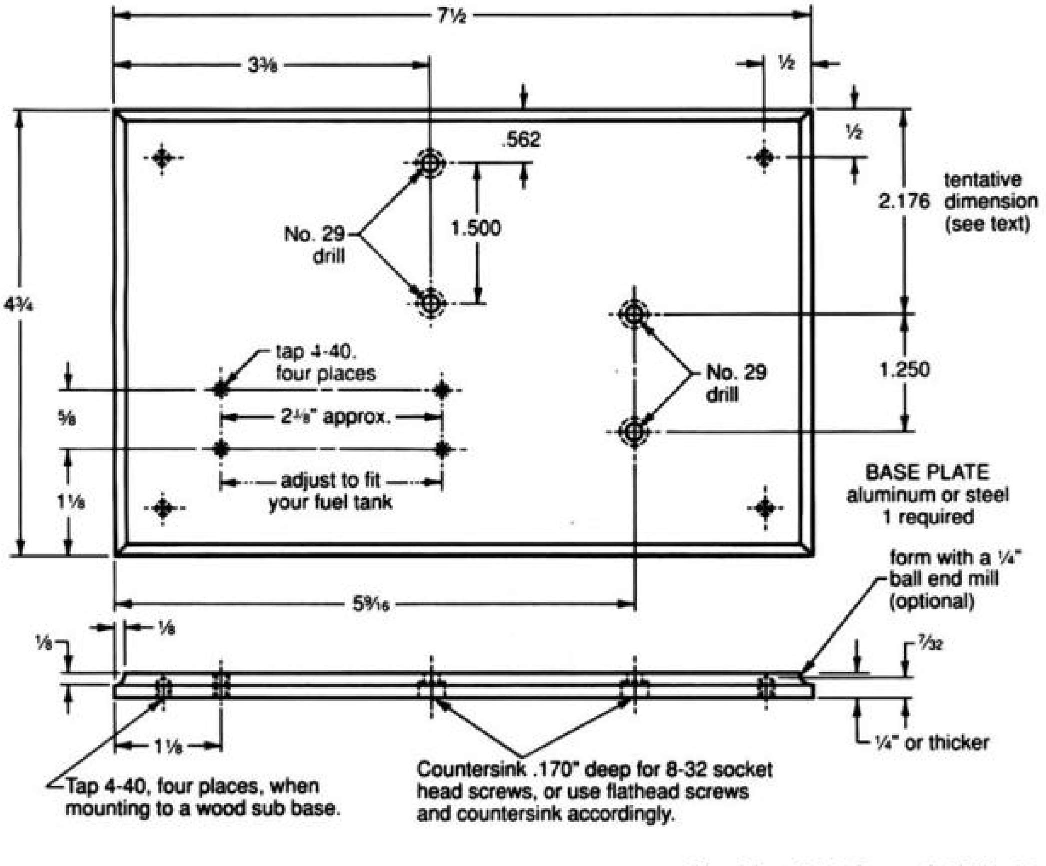
53

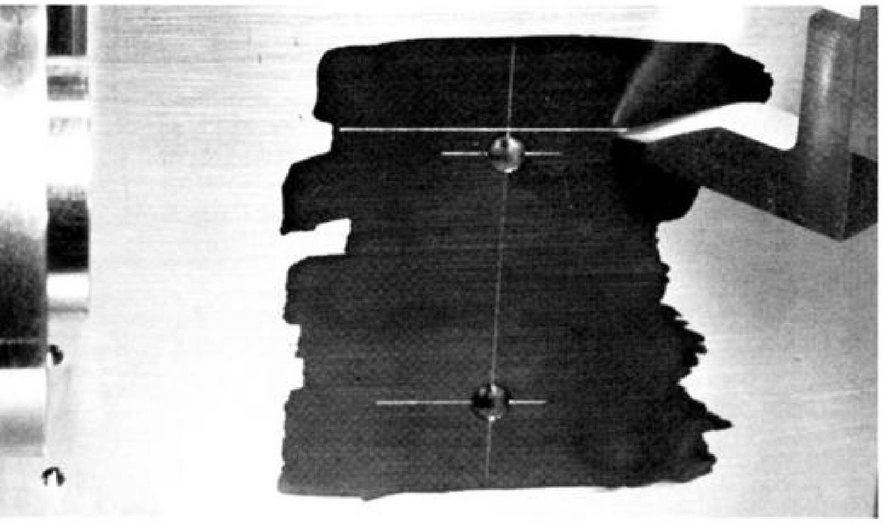


54

on the gage even with where the outer face of the crank arm will be. Now add up the thickness of the crank arm, plus the thickness of the cam, and also the fork section of the cam roller fork. To this total, add .003" for clearance. Then lower the height gage that total amount. Scribe the horizontal line as in Photo 55. In theory, the side edge of the bracket should be placed in line with the scribe. Because nothing is perfect, double check by temporarily clamping the bracket on the line. Use the setup shown in Photo 56.

Install only the valve push rod and roller fork. Both the push rod and fork should slide back and forth without binding. It could bind up and down as well as sideways. If binding occurs,


7½
3⅜
½
.562
½
tentative
2.176 dimension
(see text)
No. 29
drill
1.500
4¾
tap 4-40.
four places
No. 29
drill
1.250
⅝
2⅛" approx.
adjust to fit
your fuel tank
1⅛
BASE PLATE
aluminum or steel
1 required
form with a ¼"
ball end mill
(optional)
5⁹⁄₁₆
⅛
⅛
⁷⁄₃₂
1⅛
¼" or thicker
Tap 4-40, four places, when
mounting to a wood sub base.
Countersink .170" deep for 8-32 socket
head screws, or use flathead screws
and countersink accordingly.



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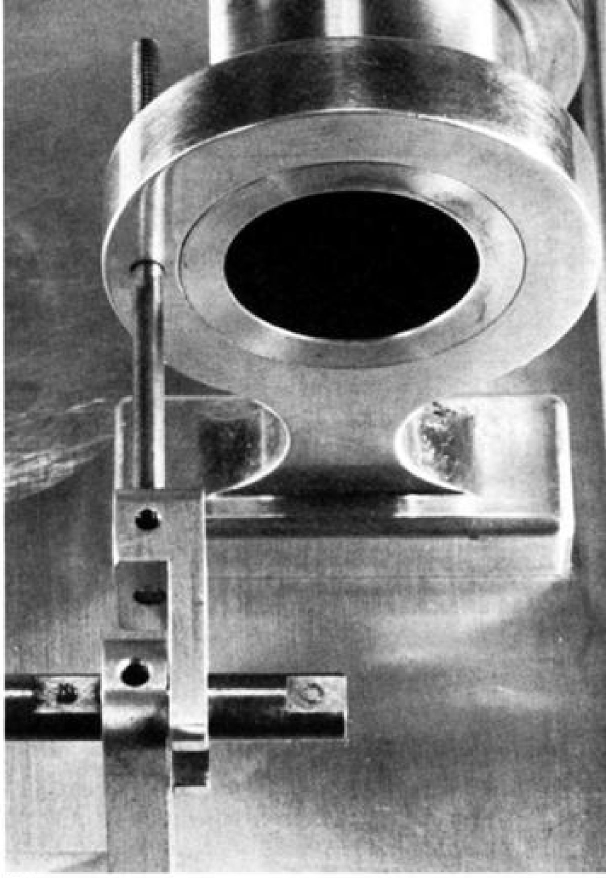


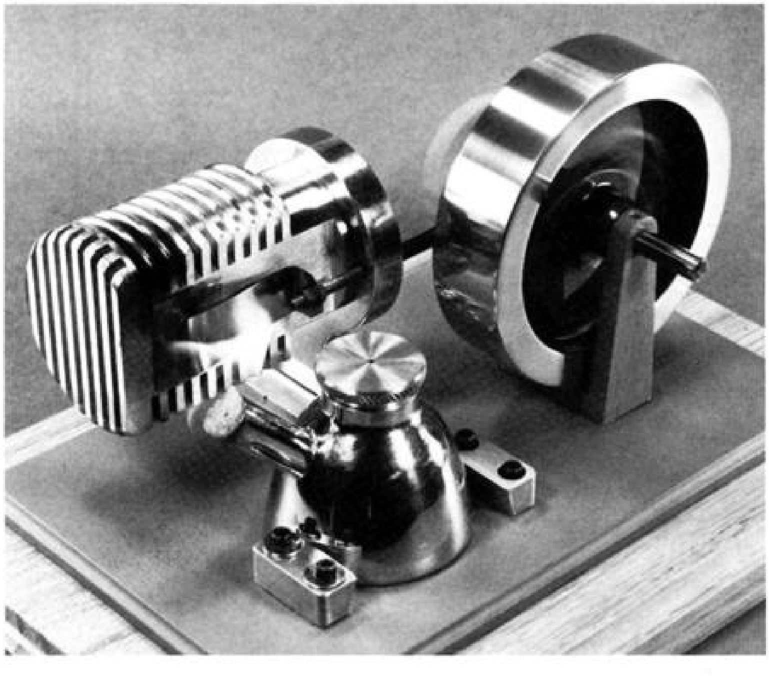
56

determine what's causing it. The bracket may have to be shifted laterally a few thousandths either direction. After everything checks out satisfactorily, scribe the center line for the first bolt hole exactly .125" below the proper guide line, then the second one below that. Again, accuracy in drilling the holes is essential for matching with the blind threaded holes in the bracket.

When assembling the entire motor, bear in mind all moving parts must function freely! First, wipe off any oil that may be in the cylinder. Coat your finger generously with fine graphite powder and thoroughly rub it all over the inside of the cylinder. Then install the piston.

The flat spring that clips to the slide valve should be bent enough to exert a little pressure against the slide valve. Rub graphite powder to the area where the slide valve moves back and forth.

The push rod compression spring should be only strong enough to keep the cam roller in contact with the cam at all times. Observe the cam roller when operating at top speed; that will tell you if the spring is strong enough.



This engine is designed to run in a clockwise direction when viewed from the fuel tank side. When the slide valve is in the closed position, the outer edge of the slide valve should only extend approximately 1/32" beyond the porthole.

For the first trial run, adjust the position of the cam so the bolt that secures it to the crank arm is approximately in the center of the curved recessed slot in the cam.

Lightly oil all of the moving parts, except the cylinder and slider valve. Don't forget the wrist pin, but wipe out any excessive oil around it, thus avoiding cylinder contamination.

The wick for the fuel tank is composed of cotton yarn, or a piece of cloth rolled up and inserted into the tube. The wick should extend inside to the base of the tank. Also, the wick in the tube should be just tight enough so the exposed end can easily be adjusted in or out.

Use only completely denatured alcohol for fuel. Not every drug store will have it in stock, so keep hunting, or ask them to order it for you. A pint will last a long time. Be certain to drill a small vent hole in the tank cover, otherwise excessive pressure in the tank will force fuel out of the spout and you'll have more fire than you bargained for!

When the engine is cold, the heat from the wick flame will usually create moisture condensation around the porthole area. This causes the slide valve to stick rather strongly to the cylinder. Prewarm the cylinder slightly with a small hand torch. Finally, position the wick flame about 3/8" away from the porthole and give the flywheel a fast turn. The motor should come to life with a definite pop! pop! Then adjust the position of the flame this way or that to control the speed.

Remember, the faster your Fire Eater goes, the hotter it gets. It's best not to run the engine at top speed longer than two or three minutes at a time. A safe speed would be around 500 or 600 rpm. Enjoy!

BILL OF MATERIALS

QTY.	PART	MATERIAL	FINISHED SIZE
1	Baseplate	aluminum or steel	4¾ × 7½ × ¼" or thicker
1	Cylinder pedestal	aluminum	¾ × 2 × 3"
1	Cylinder	aluminum, cast iron or CRS	2" OD × 3"
1	Crankshaft bracket	aluminum	¾ × 1½ × 2"
1	Flywheel	aluminum	3⅜" OD × 1"
1	Crankshaft	CRS	¼" OD × 2¾"
1	Piston	bronze, cast iron or CRS	1" OD × ¾"
1	Connecting rod	aluminum	3/16 × 5/16 × 3 11/32"
1	Crankpin retainer washer	CRS	5/16" OD × 1/32"
1	Crankpin	CRS	3/16" OD × 3/16" plus
1	Wrist pin	CRS or dri11 rod	⅛" OD × 29/32"
1	Wrist pin yoke	aluminum	5/16" OD × 11/16"
1	Crank arm	aluminum	¼ × ½ × 2"
1	Cam roller fork	aluminum	11/32 × ½ × 1⅛"
1	Cam roller	CRS	½" OD × 3/16"
1	Cam roller shaft	CRS	¼" OD × 11/32"
1	Cam	aluminum	15/16" OD × ¼"
1	Valve	CRS, cast iron, or bronze	5/32 × ½ × 15/16"
1	Valve spring	.015" spring wire	11/64" OD × 1 9/16", 32 turns
1	Valve flat spring	steel shim stock	.007 × ⅝ × 1 29/32"
1	Valve push rod	CRS or drill rod	⅛" OD × 2⅝"
1	Fuel tank	brass door knob	Weslock, stock No. SV600, *Sunray*
1	Fuel tank spout	brass tubing	7/16" OD × 1⅛"
1	Fuel tank lid	aluminum	1" OD × ⅜"
2	Tank clamps	aluminum	⅜ × 7/16 × 1"
2	Clamp springs	.025" spring wire	3/16" OD × ⅜"
4	Socket cap screws		8-32 × 9/32"
4	Socket cap screws		4-40 × ½"
1	Socket cap screws		4-40 × ⅜"
2	Hex nuts		5-40
1	Hex nuts		4-40
1	Hex nuts		6-32
2	Socket setscrews		8-32 × 3/16"
1	Socket setscrews		6-32 × ⅛"
1	Socket setscrews		4-40 × ⅛"